MANITOBA
AGRICULTURE

GUIDE TO COMMERCIAL STRAWBERRY PRODUCTION

FOREWORD

This Guide To Commercial Strawberry Production was prepared in co-operation with growers and staff of Manitoba Agriculture and the University of Manitoba.

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Introduction

There are approximately 142 hectares (350 acres) of strawberries in Manitoba. This small developing industry has an annual gross income of $1.4 million. This crop is marketed on a U-Pick basis with the major production located in the Portage la Prairie area (40 hectares/100 acres). Based on a per capita consumption of 1.98 litres (2.1 quarts), Manitoba still has a potential market for 81-121 hectares (200-300 acres) of U-Pick. The Interlake, the Northwest and Southwest Regions show the greatest potential for expansion.

The Purpose of the Guide

This guide outlines general practices and fundamentals for strawberry production in Manitoba. It is not possible to give detailed instructions that would apply to every situation. Growers should adapt the information given to their own operations. For example, frequency of spraying for insects may have to be increased in cases where early hot, dry springs result in abnormal insect populations. Similarly, fungicide sprays are basically preventative sprays that may be required more frequently during cool, wet summers. Failure to apply timely applications could result in reduced yields and quality.

To be fully informed as possible, growers should attend the field days and the strawberry seminars that are planned by the Manitoba Strawberry Growers' Association. Membership in the Association gives many benefits to the growers.

Many growers entering the industry meet the basic requirements of a good land site, with ample irrigation. However, the time and management commitment needed to raise this intensively produced crop is usually the missing factor. The belief that shortcuts in management can achieve a respectable return on investment is false. Many novice growers become attracted by the high potential return without realizing the high capital cost and management required to produce the crop.

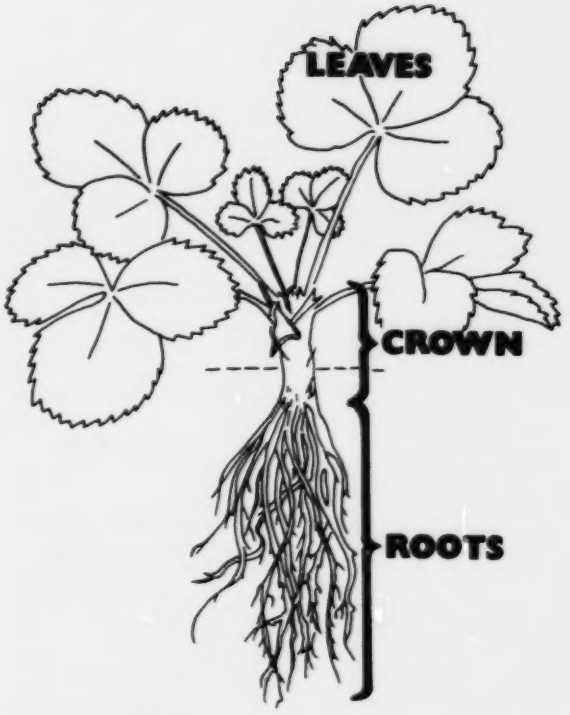


Fig. 1 The strawberry plant.
(Source: Malcom N. Dana, Fig. 1-7.)

Unlike extensive crops such as grains or oilseeds, strawberries are an intensively managed crop requiring precise timing. Yield and quality achieved during the short three week picking season all hinge on timely management practice of the previous year as well as the care and maintenance before picking.

New growers entering the industry should proceed on a small but graduated scale. Large investments such as irrigation pumps can be delayed by purchasing less expensive alternative equipment like power take-off pumps.

How the Strawberry Plant Works

Understanding the biology of the strawberry plant assists growers in adapting and modifying the general recipe of strawberry production to meet their conditions. The major parts of the plant (Figure 1) which include: the roots, the crown, the leaves and the flowers will be examined and later referred to in subsections covering cultural practices.

The Root

The strawberry plant is shallow rooted. Most of its roots are contained in the top 15 centimetres (6 inches) of the soil. The root system consists of two types of roots — the main or primary root and the secondary root which grows from the primary roots (Figure 2). A mature plant may have between 25 and 35 primary roots. They may live one or more years with new primary roots being produced at a higher level on the base of the crown. Root production and its relation to soil type, winter injury, fertilizer placement and irrigation will be covered later.

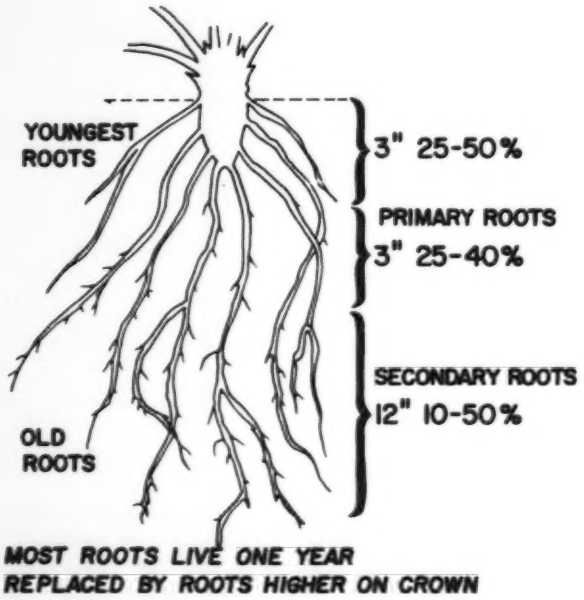


Fig. 2 Typical root system of a mature plant may have from 25-35 roots plus hundreds of secondary ones.

The Crown

The crown is a short stem where leaves develop at points called nodes. (A greatly elongated crown is show in Figure 3). These axillary buds can do three things: 1) remain undeveloped, 2) grow and form runners, 3) grow to form a side or branch crown. Environmental factors like day length and temperature influence the development of the axillary buds. During the summer's long days (14 to 16 hours), the buds develop into runners. Once the days grow shorter in August and September, the buds no longer form runners. Instead, they form branch crowns and flower buds. The more branch crowns, the greater the potential for fruit production next year as each crown produces one flower stalk. (Fig. 4 and 5)

Photo 1 — Strawberry roots.

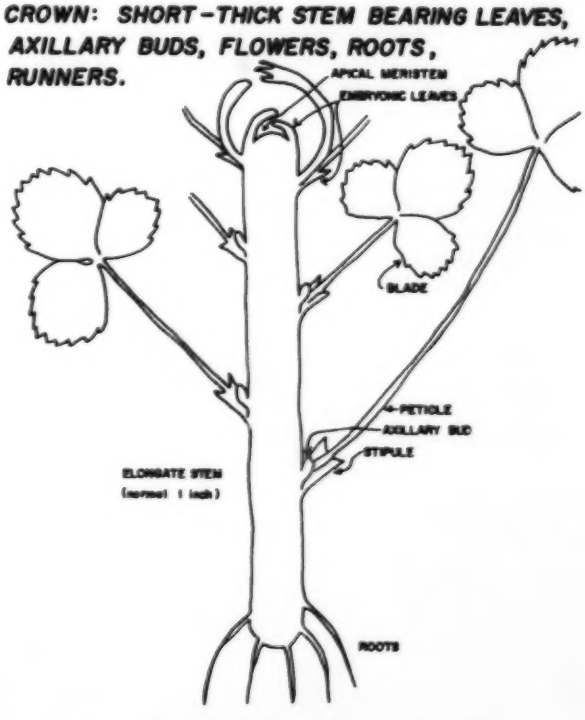


Fig. 3 — View of strawberry crown greatly elongated to show parts.

Flower Stalk (Inflorescence)

Flower buds are formed in the tip of the crown in what are known as terminal inflorescences. The inflorescence (Figure 6) has a central or primary flower that opens first in the summer. This is followed by smaller secondary, tertiary or quarternary flowers that open up in sequence. The large primary flower develops into the largest berry since it has the largest number of pistils (where the seed develops). The more pistils in a flower, the more seeds and the larger the berry. Each flower (Figure 7) has five petals and 20 to 35 stamens, the male part, with 100 to 400 pistils or female parts.

The stamens bear pollen grains which must be transferred from the stamens to the pistil before fertilization and fruit development take place. Bees transfer the pollen from the stamens to the pistil. Cool or wet weather discourages bees and results in poor pollination or partial fertilization. Misshapen fruits or nubbins will result. Temperatures below freezing will also damage developing flowers causing the stamens to blacken. The flowers in this stage will not develop into berries.

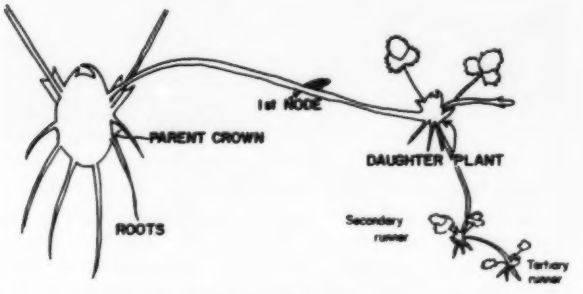


Fig. 4 — A strawberry runner (daughter plant).
Typically two nodes in length the daughter plant forms a continuation runner from the lower axillary bud.

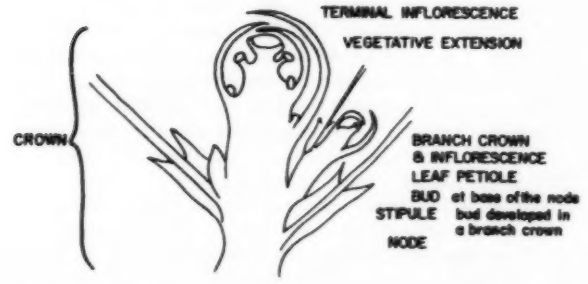


Fig. 5 — Apex of strawberry crown.

Site Selection

Soil

Suitable soil is important to successful berry production. Deep well-drained sandy loam soils, which are well supplied with humus, are best. Avoid heavy clay soils since they are usually poorly drained and make timely operations impossible. Coarse sandy soils are often infertile and droughty and require more frequent irrigation and greater attention to fertilization practices. Also avoid slightly saline soils. Strawberries have a low tolerance to salts (sensitive range 1 uS/cm).

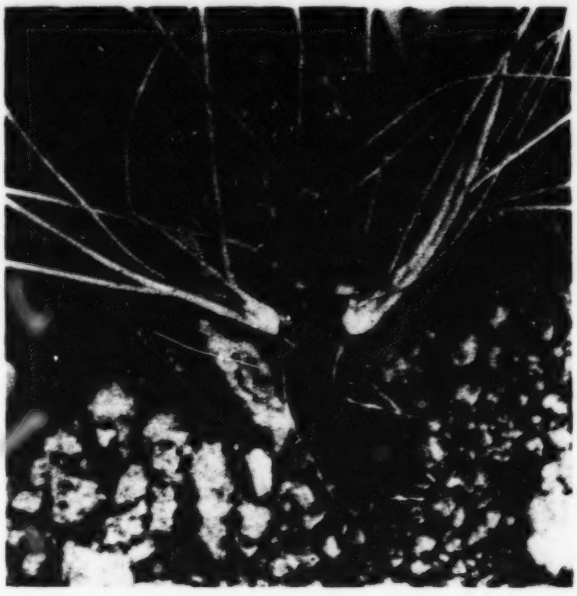


Photo 2 — A strawberry plant showing branch crowning.

The rate at which a flower develops into fruit depends on temperature. The average time is 30 days but under good conditions and high temperatures this may drop to 18 days. Adverse conditions like cool weather could extend the development 40 days or more.

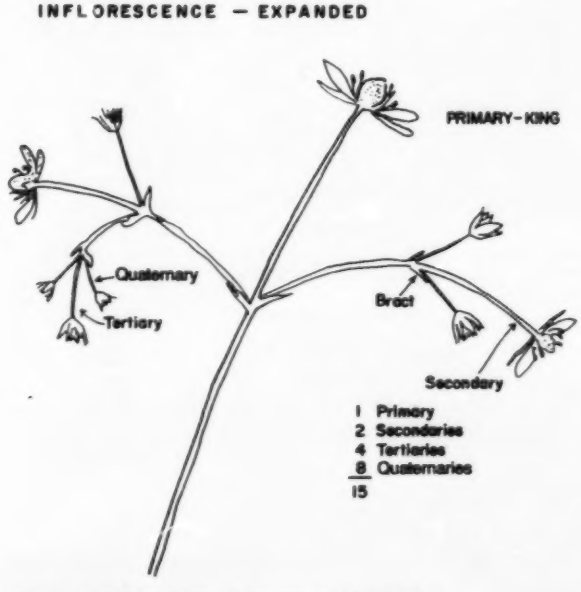


Fig. 6 — Typical strawberry inflorescence or flower stalk.

Good surface drainage that permits water to drain away quickly is important. The field should be free of depressions. Standing water, present for a day or two will injure strawberries especially when plants are growing actively. Modifications may be made to soils to improve the tilth and nutrient availability by using green manure crops such as field peas or buckwheat.

Photo 3 — Strawberry fruit.

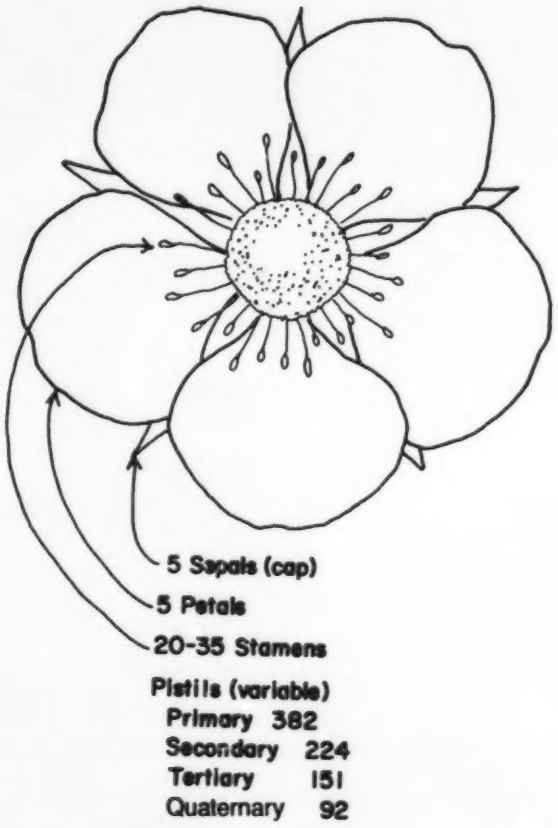


Fig. 7 — Strawberry flower.

These crops can be incorporated into a rotation program at the end of the strawberry cycle.

On sites where drainage is a problem the option of clay or plastic drains could be considered. Manitoba Agriculture, Water Services Branch, provides an advisory service for problems of this nature.

Yellowing in strawberries is a condition not directly related to disease or nutrition. It is found more in areas where there is a high pH soil or certain land contours like dips, ridges, slopes and on poorly drained sites. Avoid these sites.

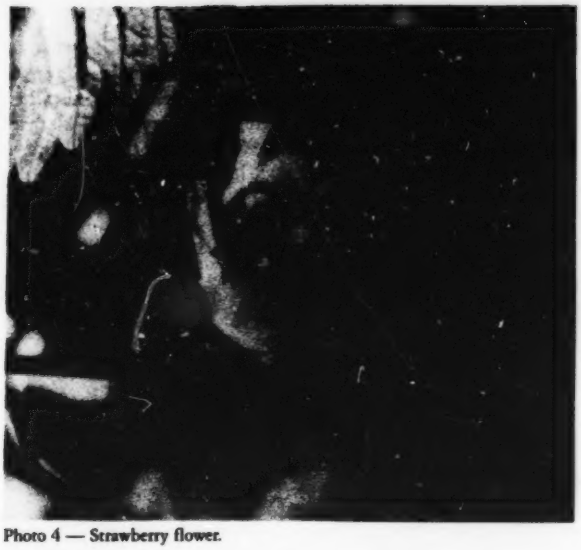


Photo 4 — Strawberry flower.

Microclimate

A suitable site is more than the availability of proper soil type and an adequate supply of good water. Exposure too, is most important. Is there protection from strong winds? If not, windbreaks to prevent plant drying or freezing may be necessary. They also prevent the winter straw from being disturbed. This item will be further discussed under Shelterbelts and Mulching.

A site needs good air and water drainage. Good surface contour that permits water to drain away quickly is important and good internal drainage is equally important. Frost pockets such as wooded areas are to be avoided. Land that is slightly sloped to provide good air and water drainage is ideal. Also, avoid soils that tend to puddle or easily water log. Strawberry plants are shallow rooted and very sensitive to saturated soils even over short periods of time especially during active growth. Modifications may be made to soils to improve the texture by using green manure crops. Subsoiling and drainage tiles can be used to improve poor soil drainage on small parcels of land.

Some areas in Manitoba are subject to lower temperatures than the rest of the province, especially in early spring. Also, there are parts of Manitoba that have less snow that other areas. Such places are not ideal for commercial strawberry production.

Previous Crops

Strawberries should not be grown in soils where strawberries, raspberries, alfalfa, potatoes, tomatoes, peppers or eggplants have been grown in the previous four years unless the soil has been fumigated. When strawberries are grown frequently on the same site, organisms in the soil cause black root rot disease.

Strawberries are also susceptible to tuber verticillium wilt, which is caused by a soil fungus that builds up when these crops are grown repeatedly in the same soil.

Where a proper long-term rotation is not feasible because of limited production area or the distance of alternative fields from a portable water supply, consider fumigation. At present, there is not enough information on soil fumigation in Manitoba soils to make definite recommendations, although this is being evaluated.

Water Quality For Irrigation

Irrigation is essential for both consistent high yield straw-

berry production and frost control. Since Manitoba has fairly low rainfall, and strawberry plants are shallow rooted, supplementary moisture is important. To maximize production, an average of 30 centimetres (12 inches) of irrigation is required over the growing season. River water or water from ponds is generally used. Well water may be suitable. More water may be required for frost control and crop cooling when there are above average summer temperatures. A Water Rights Licence issued by the Water Resources Branch, Department of Natural Resources is required before water can be taken from any source except from a pond that is filled completely by rain or snow that falls on the grower's premises. Construction of ponds or dams may also require approval.

There are a number of assistance programs for development of irrigation systems. Further details can be obtained by contacting the Manitoba Water Services Board, Manitoba Agriculture, P.O. Box 1059, Brandon, Man., R7A 6A3.

The suitability of a water source may be tested by submitting a two litre sample to the Technical Services Lab., Department of the Environment, 745 Logan Avenue, Winnipeg, R3E 1M8 for Test Number 83. Salinities less than 1 uS/cm, an adjusted sodium absorption ratio (SAR) less than 3, and chlorides less than 3 milli equivalents/litre should be satisfactory for strawberries.

Shelterbelts

Shelterbelt planting may be considered if tree protection is lacking. Using shelterbelts for small fruit production reduces wind velocity, which can dry plants during the growing season or during the dormant winter period. In winter the shelterbelt assists in the uniform coverage and distribution of snow as an insulating mulch cover.

There are a number of ornamentals suitable for shelterbelt rows each having its own advantages and disadvantages. Ideally the hedge should grow quickly and take up minimal land, especially in terms of competition for fertilizer, moisture and light (shading factor).

In selecting shelterbelt ornamentals, avoid these characteristics:

- over density of branches inhibiting snow infiltration
- widespreading top
- high labor for pruning
- susceptibility to snow and windbreakage
- suckering roots
- high seedling production

Since shelterbelts do not permit the strawberries that grow close to them to develop properly, have grassed areas on both sides of the shelterbelt. Plant the shelterbelts 122-152 metres (400 to 600 ft.) apart and in a direction which breaks the force of prevailing winds. Do not align the shelterbelt so that it blocks natural airflow patterns, especially on slopes. Frost pockets can be created causing frost risk in these areas. Weed control, especially of broadleaf weeds, in shelterbelts is a must. Poorly maintained shelterbelts (weed and leaf litter accumulations) foster slug populations.

Supplementary Shelter

In Manitoba, planting supplementary shelter every 18 metres (60 ft.) or so has been advantageous. Corn and sunflowers have been tried. Sunflowers, the Russian cultivar Peredovik or Saturn (open pollinated) or the confectionary type of Sandaks, have been found most suitable. Sunflower stalks break the wind just enough to disperse the snow over a wider area instead of causing higher drifts close to the sunflower row.

When establishing a sunflower hedge, plant as early in the spring as possible but do not over seed. Ensure good fertility so maximum stock development can take place over the summer. If properly managed, a sunflower hedge lasts several years. Remember, remove the flower heads before maturity to avoid the "heads" going to seed.

The use of snow fence can also be considered as it makes fuller use of a field possible. Plant competition for moisture and nutrients is eliminated.

Markets

Select a site close to all weather roads with a large enough area for marketing the produce. Adequate parking is also essential as most of Manitoba's production is marketed on a U-Pick basis and is geared to the urban residents.

Fertilizers

Soil Testing

The strawberry plant is very sensitive to salts (salinity). Since many of Manitoba's soils have salt contents too high for successful commercial production, take a soil test to determine its suitability.

Early soil testing is an important management practice for maximizing yields. Estimates based on general recommendations are not sufficient for maximum yields.

Fertilizer recommendations are only as good as the quality of your sample. When soil sampling, take a series of samples that represent the area. Instructions on the proper procedure of taking soil tests may be obtained from your agricultural representative or the Provincial Soil Testing Laboratory at the University of Manitoba Campus. Also, see the Manitoba Agriculture Factsheet *Soil Testing Services in Manitoba*. Key points to remember in soil testing are:

- use proper augers and containers for sampling
- sample well before transplanting or renovating so there is enough time for the sample to be processed and the recommendations returned
- the sample depths used include 0-15 centimetres (0-6 inches) and 15-60 centimetres (6-24 inches)
- do not sample in locations where fertilizer has recently been incorporated
- air-dry the soil sample immediately after sampling (this is often overlooked by growers)

Soil testing not only determines the suitability of a field for strawberry production but is basic to making fertilizer recommendations.

Field Description and Cropping History

This information enables the lab to maintain records for research purposes. More important, it assists in interpreting the analytical results making sound fertilizer and management recommendations for the grower.

Soil Test Reports

Soil testing gives considerable information. The following details should assist in understanding the charts that are returned after a soil test.

Carbonate Content — Indicates the presence or absence of calcium carbonate. High to very high calcium carbonate levels in the soil can affect nutrient availability to plants. Absence of calcium carbonate does not mean the fields require lime as most Manitoba soils have sufficient lime. Only very acid soils require recommendations for lime.

pH — This indicates the acidity or alkalinity (basidity) of the

soil. Soils with pH in the range of 5.5 to 8.5 are usually satisfactory for plant growth. pH is important because it influences the solubility or availability of mineral elements. Phosphorus, for example, becomes less available at levels below pH 5.3 and above pH 7. Potassium solubility is hampered when levels are between 7.5 to 8 or greater. Nitrogen is available in the pH 5 to 8 range. Soil pH's greater than 7.5 have been associated with yellowing of strawberries caused by lack of iron uptake by the plant.

Conductivity — Measure of the salinity (salt) level of the soil

A conductivity reading of less than 1 uS/cm is best for strawberries. Levels greater than 1 could result in growth problems and reduced yields. The addition of lime or gypsum will not correct the salinity problem in the soil.

Texture — This reading indicates the relative amounts of sands, silts or clays. Loam soil is a good mixture of sand, silt and clay and is neither droughty nor difficult to till.

Nitrogen — Nitrate nitrogen levels are indicated in kilograms per hectare or parts per million. Nitrate-nitrogen is the form of nitrogen most readily used by plants. Soil nitrate-nitrogen levels to 60 centimetres (2 ft.) are rated as follows:

0-29 kilograms/hectare is low range (0-26 lbs/acre)
30-44 kilograms/hectare is a medium range (27-40 lbs/acre)
45-69 kilograms/hectare is a high range (41-63 lbs/acre)

Soils containing in excess of 69 kilograms/hectare (63 lbs/acre) nitrate-nitrogen receive no recommendations for additional fertilizer nitrogen.

Nitrogen is one of the more significant fertilizer nutrients used in managing a strawberry crop. (See Table 1).

Phosphorus — This reading describes the ability of the soil to supply phosphorus. It is measured in kilograms per hectare or parts per million. Phosphorus and potassium are measured in only the surface depth of the soil 0-15 centimetres (0-6 inches). Phosphorus levels are rated as follows:

0-11 kilograms/hectare is very low (0-10 lbs/acre)
12-19 kilograms/hectare is low (10-18 lbs/acre)
20-28 kilograms/hectare is medium (18-26 lbs/acre)
29-40 kilograms/hectare is high (27-36 lbs/acre)
41-100 kilograms/hectare is considered very high (37-89 lbs/acre)

Potassium — Potassium readings are measured in kilograms per hectare or parts per million and are a measure of the ability of the soil to provide potassium. Many Manitoba soils have sufficient potassium. The soil potassium levels are rated as follows:

0-96 kilograms/hectare is very low (0-85 lbs/acre)
96-196 kilograms/hectare is low (85-170 lbs/acre)
196-287 kilograms/hectare is medium (171-258 lbs/acre)
288-383 kilograms/hectare is high (259-403 lbs/acre)
384-448 kilograms/hectare is very high (343-400 lbs/acre)

Potassium (potash) has also been associated with increased winter hardiness in strawberries.

Sulphur — Sulphur readings are measured in kilograms per hectare or parts per million. This figure indicates the amount of sulphate-sulphur present in the top 60 centimetres (2 ft.) of soil. Some growers have found it beneficial to use fertilizer containing sulphur so that the equivalents of 56 kilograms/hectare (50 lbs/acre) are used at renovation.

Soil tests are not only an initial guide, but an important yearly management practice for obtaining maximum yields.

Plant Tissue Testing

Soils are analyzed to determine the availability of plant nutrients. This enables the grower to estimate the fertilizer nutrient requirements before production. Plant tissue testing is another method used to find out if nutrients in the soil are being

Table I Recommendations for Fertilizer Addition Based on Soil Analysis Results

Soil Nitrogen Content (NO_3N) kg/ha in 0-60 cm depths	Nitrogen Availability Category	Nitrogen (N) Recomm. kg/ha Fruit Crops	Exchangeable Potassium in soil kg/ha in 0-15 cm depth	Potassium Availability Category	Potassium (K) Recomm. kg/ha Fruit Crops
0-4	VL−	140-130	0-31	VL−	225-213
5-9	VL	130-121	32-63	VL	213-201
10-14	VL+	120-111	64-93	VL+	201-189
15-19	L−	110-101	96-127	L−	189-177
20-24	L	100-91	128-159	L	177-165
25-29	L+	90-81	160-191	L+	165-153
30-34	M−	80-71	192-223	M−	153-141
35-39	M	70-61	224-255	M	141-129
40-44	M+	60-51	256-287	M+	129-117
45-49	H−	50-41	288-319	H−	117-105
50-54	H	40-31	320-351	H	105-93
55-59	H+	30-21	352-383	H+	93-81
60-64	VH−	20-11	384-415	VH−	81-69
65-69	VH	10-1	416-447	VH	69-55
70+	VH+	0	448+	VH+	0
Extractable Phosphorus (P) in Soil kg/ha in 0-15 cm depth	**Phosphorus Availability Category**	**Phosphorus (P) Recomm.**	**Soil Sulphate Sulphur Content SO_4S kg/ha in 0-60 cm depth**	**Sulphur Availability Category**	**Sulphur (S) Recomm. kg/ha Fruit Crops**
0-11	VL	110-102	0-11	VL	30
12-19	L	101-96	11-22	L	30
20-28	M	95-89	23-33	M	30
29-40	H	88-81	34-44	H	0
41-100	VH	80-35	45-66	VH	0
101+		0	67+	VH+	0

taken up in adequate amounts by the strawberry plant. Several factors including soil temperature, root development, method of fertilizer application, and timing can affect the plant's ability to use fertilizer under adequate soil supply conditions.

Tissue testing results are useful for planning and implementing management practices to avoid nutrient problems in subsequent years. Occasionally, severe nutrient problems are encountered early in the growth of a crop. A tissue analysis may allow for proper measures to be taken in the same season to overcome the problem and reduce potential loss.

Table 2 Plant Analysis Values for Determining the Mineral Status of Strawberries (Dry Weight Basis)*

Nutrient	Plant part tested	Tentative critical concentration	Range showing Deficiency symptoms	Range showing No deficiency symptoms
Boron: B	Blade	25 ppm	18-22	35-200
Calcium: Ca	Blade	0.3%	0.08-0.20	0.4-2.7
Chlorine: Cl	Petiole	—%	<0.07	0.07-0.4†
Copper: Cu	Blade	3.0 ppm	<3.0	3-30
Iron: Fe	Blade	50 ppm	5-40	50-3000
Magnesium: Mg	Blade	0.2%	0.03-0.10	0.3-0.7
Manganese: Mn	Blade	30 ppm	4-25	30-700
Molybdenum: Mo	Blade	0.5 ppm	0.12-0.40	0.5+
Nitrogen: NO_3^- – N	Petiole	500 ppm	0-500	700-20,000
Total – N	Blade	2.8%	2.0-2.8	3.0+
Phosphorus:				
$H_2PO_4^-$ – P	Petiole	700 ppm	150-700	1,000-5,000
Total – P	Blade	1,000 ppm	300-1100	1,500-13,000
Potassium: K	Petiole	1.0%	0.1-0.4	1.0-6.0
	Blade	1.0%	0.1-0.5	1.0-6.0
Sodium: Na	Blade	—	<0.01	0.01-0.4†
Sulfur: SO_4 – S	Blade	100 ppm	25-80	100-500†
Total – S	Blade	1,000 ppm	300-900	1,000+
Zinc: Zn	Blade	20 ppm	6-10	20-50+

Source: Strawberry Deficiency Symptoms, A. Ulrich et al.

Micro-nutrients (zinc, copper, manganese, boron, chlorine, iron and molybdenum) rarely affect the plant growth. However, imbalances in application of major nutrients like nitrogen, phosphorus, potassium, sulphur and pH levels (acidity and alkalinity) can affect micro-nutrient availability. These deficiencies may affect plant vigor and berry quality. With iron deficiencies, tests have shown yield reductions of 15%.

Normal nutrient levels in strawberry tissue analysis vary with a plant's growth stages such as flowering, fruiting and after fruiting. (See Table 2)

Factors that affect tissue values include time of sampling, the age of the leaves, and the cultivars used. However, deficiency levels are reliable indicators that nutrient additions are required.

As in soil sampling, the correct procedures for tissue test sampling are important. These considerations include:

- cleanliness in sampling and handling
- the use of proper sampling equipment
- taking the plant part at the proper time of growth
- taking a representative sample and immediately cleaning and drying with a dry cloth or brush
- avoiding samples that have fertilizer contamination, pesticide residues and soil particles
- not collecting tissue in metal containers — use a clean brown paper bag
- taking samples from a reasonable number (25-30) of typical plants throughout the field
- avoiding non-typical plants and areas in the field which may affect a normal sample
- using the youngest expanded mature leaf as the sample
- not washing the sample
- drying the sample at room temperature

Send tissue samples to:

The Manitoba Provincial Soils Testing Laboratory
Manitoba Agriculture
262 Ellis Building
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

Further information on plant tissue analysis is contained in the Manitoba Agriculture Factsheet *Plant Tissue Analysis*.

Application of Fertilizers

Fertilization Requirements

Nutrient requirements for a field, and the conditions that alter the nutrient levels are unique. For example, a harvested bumper crop of 4 500 kilograms per hectare (10,000 lbs/acre) of strawberries removes less than 5.6 kilograms/hectare (5 lbs/acre) of phosphorus. Approximately 22.4 kilograms/hectare (20 lbs/acre) of potassium are also removed. Besides fruit production larger amounts are used for leaf and stem growth.

Most leaf minerals are returned to the soil as the leaf dies and is incorporated back into the soil at renovation. Nitrogen, one of the most important nutrient elements in strawberry production, can be affected by a number of environmental factors like rainfall and irrigation. Under saturated soil conditions, nitrate-nitrogen is rapidly converted to gaseous nitrogen and is lost, therefore unavailable for uptake by the plant.

Soil tests determine which major nutrients are available at the beginning of a strawberry program. The objectives of fertilization are:

- to promote rapid growth and early runnering of new plants
- to promote rapid growth and development of early runner formation before the end of July and maximum crown formation after late August of the establishment year

An adequate supply of phosphorus is necessary to produce early daughter plants and encourage good vegetative growth and runnering. Give special attention to phosphorus requirements in the pre-planting application of fertilizers.

High nitgrogen levels may very likely increase the number of runners. This could be a disadvantage for maximum production. Too many runners create a high population and competition, a factor which may be more important than fertility. But, on the positive side, high nitrogen levels in the summer may encourage more branch crown formation and benefit overall production.

Nitrogen applications, depending on timing, can affect runnering, branch crown formation, leaf and berry size. Poor timing can reduce yield and fruit quality. In late summer and early fall, flower buds for next year's crop form. Research has shown that nitrogen applications in late summer often promotes flower bud formation. However, nitrogen application in late fall may delay normal dormancy and cause increased winter injury.

Avoid excessive nitrogen in the bearing plants. In the early spring excess nitrogen favors the development of large and plentiful leaves that may overtop flowers and discourage pollination. Also, larger leaves tend to maintain wet conditions near the ground favoring fruit rot. Limit the use of nitrogen applications to the spring of the fruiting year.

There are some exceptions to this rule. For example, heavily mulched plants lack nitrogen since it is used by soil organisms to break down the straw. It has been found that up to

11.1 kilograms/hectare (10 lbs/acre) of actual nitrogen applied in this case can increase berry size and yield, provided adequate fertilizers were used at renovation. Fields that have undergone severe winter injury or in general are lacking in vigor will respond to a similar treatment of nitrogen 2.7 kilograms of urea in 455 litres of water at the rate of 2 246 litres/hectare (6 lbs in 100 gals at 2000 gals/acre) as a foliar spray in the early spring.

Foliar Application of Fertilizers

Fertilizers may be sprayed on the leaves as a supplement to soil application. Foliar applications offer a quicker response to fertilizer as compared to soil feeding and are very useful in perking up plants that have damaged root systems from winter injury or frost damage. Generally, any stand that is poor or lacking in vigor may benefit from this procedure. This is particularly the case in third or fourth year fields.

Supplementary addition of trace elements such as iron, magnesium, boron, calcium and macro-nutrients like nitrogen can be applied by foliar spraying. To avoid leaf burn, nutrient sprays should not be applied during hot weather. Application of foliar spraying during early growth enhances its effectiveness. Do not apply pesticides and nutrients together.

Fertilizer Application Through Irrigation

Strawberries require uniform water coverage. This can be checked by inserting a gauge in the nozzle. The minimum pressure should be 20 kilopascals (30 psi). Pressure at the nozzles should not vary more than 20%.

Fertilizers that can be spread by irrigation include: ammonium sulphate, ammonium nitrate, calcium nitrate, ammonium phosphate, muriate of potash, urea and borax. Do not apply phosphoric acid (corrosive), anhydrous ammonium and ammonia (solutions lost to the air), superphosphates and lime (do not dissolve in water). To avoid burning the foliage, run the system until the plants are wet.

The fertilizer is dissolved in a drum then introduced through a valve into the irrigation line either by suction or by pressure over a 10 or 15 minute span (Fig. 8, 9, 10). After the application is complete leave the sprinklers on for 30 minutes to wash off all fertilizer from the plants. Do not fertilize too early during the irrigation; nutrients may be leached if too much water is applied after the fertilizer injection.

Calculating the Rate

At a 12 x 18 metre (40 x 60 ft) sprinkler spacing 0.02 hectares are covered by each sprinkler. So 12 sprinklers, at the same spacing, would cover 0.24 hectares (0.6 acres). To apply 56 kilograms of fertilizer per hectare (50 lbs/acre) at this setting add .24 x 56 = 13.44 kilograms (29.6 lb) of fertilizer to the system.

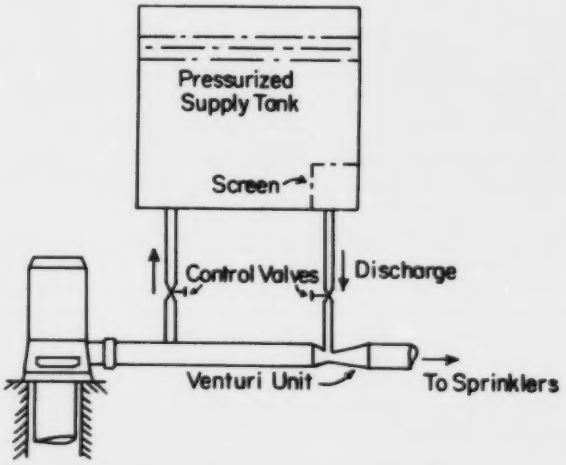


Fig. 9 — Venturi principle of injection.

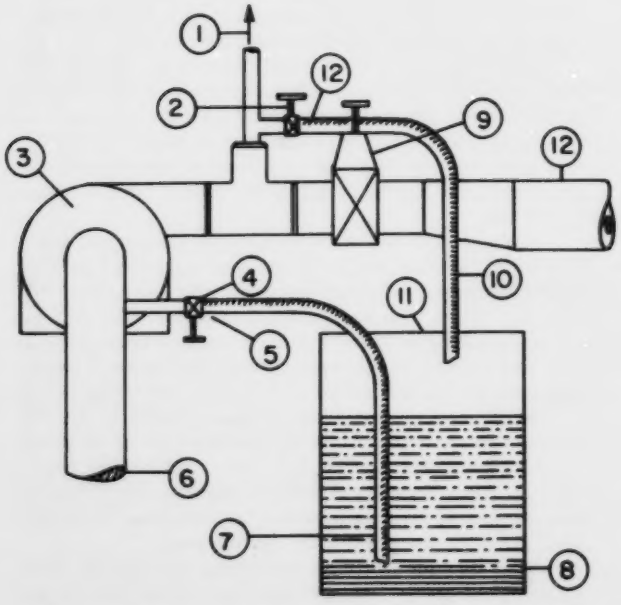


Fig. 8 — Installation for applying fertilizers.

1 To priming device.

2 Install ¼" globe valve on priming device line or directly to discharge line using ¼" pipe.

3 Pump.

4 Install ¼" globe valve in vertical downward position to prevent air leakage.

5 Hose connected to suction line permits fertilizer solution from barrel to be injected into system.

6 Suction line to water intake.

7 ¾" hose to be as short as possible, screen if nozzle plug occur during application.

8 45 gallon drum containing fertilizer solution.

9 Valve on discharge line.

10 ¾" hose.

11 Top of drum removed.

12 Hose connected to discharge line allows barrel to fill with water — globe valve regulates flow.

(¾ inch = 1.905 cm)
(1 gallon = 4.546 L)

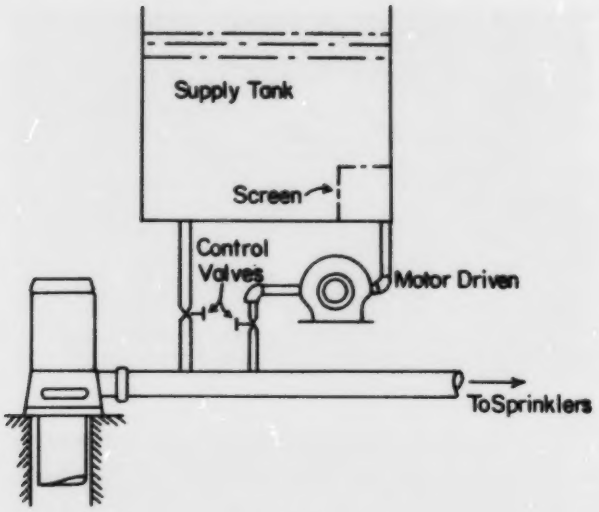


Fig. 10 — Pressure pump injection.

Irrigation

Strawberry-Water Interrelationships

Strawberries are shallow rooted with 90% of the root found in the top 15 centimetres (6 inches) of soil. As a result it has a low tolerance to drying and poor drainage. It also has a low tolerance to salt, becoming sensitive around 1 uS/cm. Yields decrease by 33% for each unit increase in salinity above this 1 uS/cm threshold. Water with a pH greater than 8 may contribute to a yellowing of strawberries, caused by iron chlorosis, especially in soils with a pH range greater than 7.5. It has been recorded that a 2.5 fold increase in yield can occur with some cultivars under irrigation versus non-irrigated strawberries.

Strawberry Irrigation Requirements

Strawberries need 62 millimetres of water/hectare/week (1 inch/acre/week), excluding what's needed to control frost. This works out to 750 millimetres/hectare (12 inches/acre) for the 12 week growing cycle. It is best to irrigate early in the day to reduce evaporation losses. Straw mulch also greatly reduces evaporation from the soil. During the growing season strawberries draw about 4 millimetres (0.15 inches) of water a day from the soil.

Strawberries have been grown without irrigation, however, the fruit lacks consistency in yield and quality. Some irrigation is also needed for frost control and crop-cooling. Naturally light sandy soils require more frequent irrigation than heavier soils.

To see if the soil moisture is sufficient use the hand test method; brush away the surface of the soil and take a handful of soil, squeeze it lightly. Upon opening your hand if the soil ball breaks apart readily your soil needs water.

Avoid irrigating just prior to picking. Based on two day picking intervals irrigate immediately after picking.

Key Irrigation Times For Strawberry

The purpose of irrigation in strawberries is to produce large plants with large leaf surfaces which in turn produce more flowers. It also aids the establishment of a new planting, runner rooting, frost control, fruit bud initiation and development and crop-cooling. Irrigation is also used to incorporate herbicides and fertilizers. Irrigation prevents drought stress especially during flower bud initiation which occurs in the fall. Key times for irrigation include:

- establishment
- initiation of berry set
- maximum final enlargement of the fruit to minimize water stress
- before signs of wilting occur, otherwise berry size is greatly reduced
- renovation, when fruit buds are forming
- fall just prior to covering — soil moisture should be high in the fall to reduce winter injury

Other points to consider:

- excess irrigation leaches herbicides and nutrients
- excess irrigation can reduce yields, affect fruit quality and increase fruit rots

Selecting an Irrigation System

There are a number of systems and accessory equipment to choose from. The factors to consider in selecting a system are: site, cost, labor and suitability to the crop. Trickle, pivot and large gun systems, for example, deliver water but are unable to provide frost control. Good systems will have proper size sprinklers, pipelines, pump, filters and be well laid out. Consult an irrigation specialist for details on an irrigation system layout.

A balance should be maintained between pipe costs and power costs. The larger the pipe the higher the installation cost. However, smaller pipes are less expensive to purchase but require more pumping power due to increased water friction.

Planning an Irrigation System

A basic plan should contain the following:

- a map showing the field boundaries
- water source location
- water level
- natural gas and electrical powerlines
- elevations around field boundaries
- highest and lowest points in the proposed irrigated area
- kind and depth of soil
- rate water enters the soil
- soil capacity to hold water for plant use
- the amount of water available for irrigation
- power source
- labor requirements — operation and maintenance — moving pipes (critical times)

A Solid Set Irrigation System for Strawberries

A solid set system is designed to apply water uniformly over the entire crop at one time. It is an expensive system but little labor is required (semi-permanent placement of lines). It can be used for frost control and crop-cooling. It can also be adapted to irregular shaped fields with various topographies and slopes. Figure 11 shows a sample layout of a solid set system.

Components

A solid set system basically consists of:

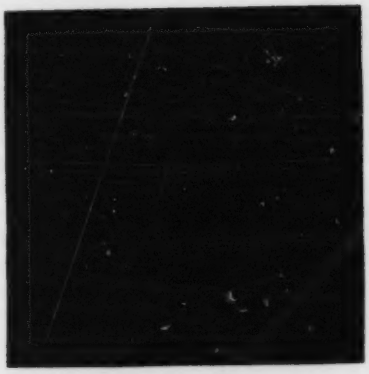
- A main line
- Lateral lines
- Sprinkler heads
- Risers
- A pump

Main Line: A main line can be buried or above ground but plastic piping is used if the line is buried. The size of the line can range from a diameter of 15 to 30 centimetres (6-12 inches).

Laterals: The diameter of the pipe is 5 to 10 centimetres (2-4 inches).

Tarnished plant bug on strawberry flower.

Slug and damaged fruit.



Fruit damage caused by tarnished plant bug.

Powdery mildew infected plants.

Strawberry Weevil.

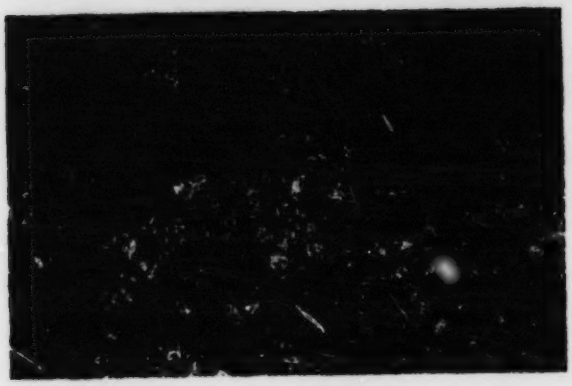
Grey mold infected fruit.

Weevil damaged strawberry stalk.

Leafspot on strawberry leaf.

Slime mold on strawberries.

Winterkill in strawberries.



Virus infected plants.

Winter injury to strawberry crown.

Yellowing in strawberries.

Frost damage to flower bud.

Calcium leaf deficiency.

Frost tip burn to leaves.

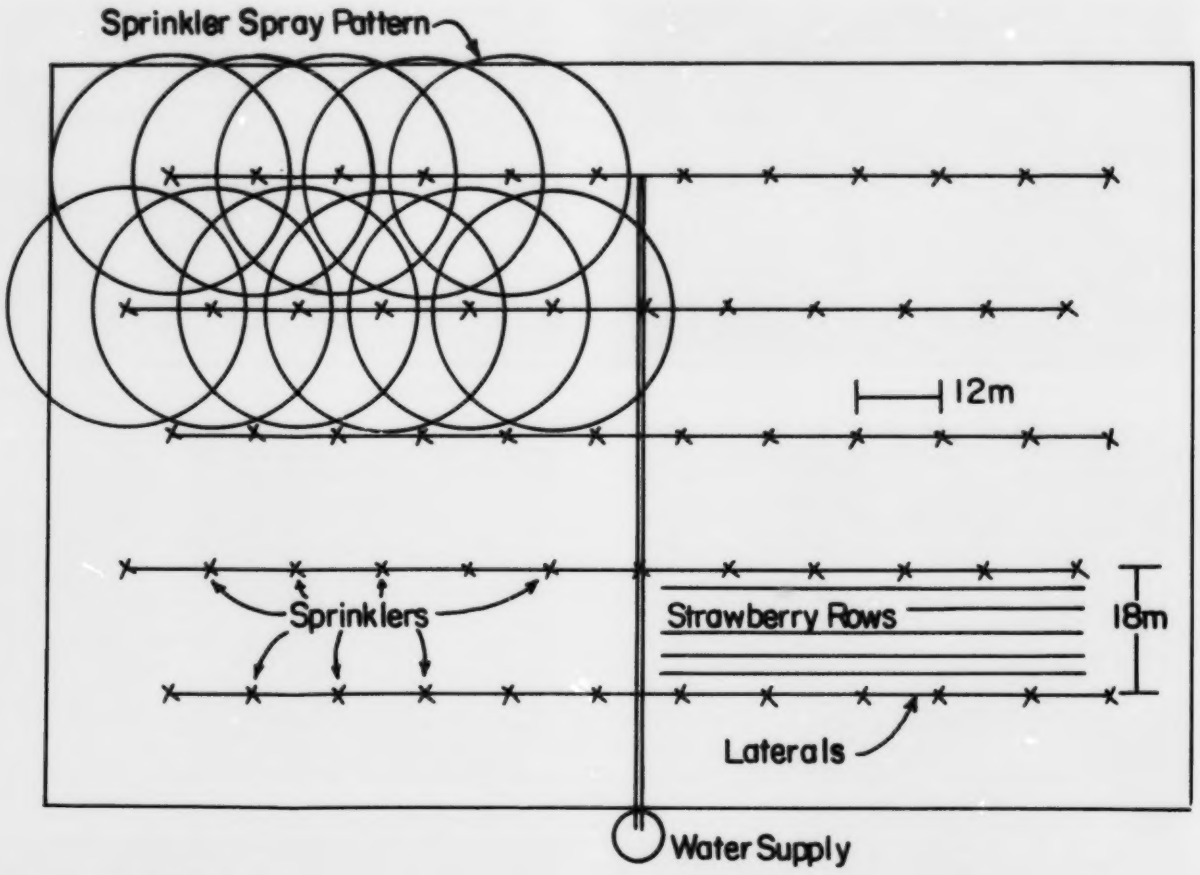


Fig. 11 — A solid set irrigation system.

The type of latch coupling varies with the company and generally these are not interchangeable. Spring couplers are not ideal if the system is constantly moved. Rubber gaskets inside the coupler seal the line against leakage while the system is operating. Self-draining couplers prevent rupture from freezing but are not suitable for fertilizer or pesticide injection applications.

Lateral lines are normally spaced 18 metres (60 ft) apart, with sprinklers placed every 12 metres (40 ft) along the lateral. This is commonly referred to as a 12 x 18 metre (40 x 60 ft) pattern (See photo 4). Depending on the sprinkler selection a 12 x 18 metre pattern should give reasonably uniform water application when the wind is less than 16 kilometres per hour (10 mph).

Sprinkler Heads: The rotary sprinkler operates on the principle of an impact arm which is deflected by the jet of water from the nozzle. Spring tension returns the arm to the original position. The impact of the arm against the sprinkler body causes it to rotate.

Ten degrees of frost can cause ice buildup on the sprinkler heads and prevent the head from rotating.

An application of 2.5 to 3 millimetres/hour/hectare (1/10-1/8 inch/hr/acre) of water is required to control frost damage to the plants. This requires a minimum of one revolution per minute with the system we have described.

Ideally the sprinkler should have one nozzle — the other tip is plugged. When 2 nozzle heads are used the smaller nozzle head plugs with debris.

The sprinkler heads should not be placed opposite each other on laterals that run beside each other. Rather, they should be offset, forming a triangular spacing pattern rather than a rectangular one.

Be sure sprinkler heads are placed on the ends of the rows to provide adequate coverage on the field perimeter. A 50 millimetre (2 inch) diameter lateral can support up to 16 sprinklers. There will be a difference in pressure of approximately 20% between the first and the last sprinkler on the lateral if the field is level. For an application rate of 3 millimetres/hectare (1/8 inch/acre), using a 12 x 18 metre sprinkler pattern, the water flow per sprinkler should be approximately 11 litres per minute (3 gal/minute).

To set up a 12 x 18 metre (40x60 ft) sprinkler pattern would require 46 sprinklers per hectare (18/acre).

Risers: The sprinklers are connected to a rise pipe which attaches to the lateral pipe couplers. These range in size from 15 to 60 centimetres (6 to 24 inches). The ideal height is 30 centimetres (12 inches); risers higher than this height cause problems with field sprayer booms and other strawberry field equipment.

Pump: It is important to have a very reliable pump which will not break down, especially when water is needed to control frost. It is questionable whether PTO pumps can provide the trouble free reliability needed for frost control; although PTO

Photo 5 — Strawberry field being irrigated by solid set system.

pumps and several hand-move laterals may provide an inexpensive irrigation system for the establishment year. For an application rate of 3 millimetres/hectare (⅛ inch/acre) the minimum pump capacity required is 500 litres/minute/hectare (55 gals/minute/acre). Select a pump that provides the required flow at a pressure which can be maintained despite pressure drop through sprinklers, lines, fittings, and changes in elevation between the water source and the sprinklers.

Economic Considerations

A solid set irrigation system cost about $6,200 per hectare ($2,500/acre) in 1983. No return on investment can be expected for the first year. This system also has a higher cost per unit area on smaller operations.

Special Applications of Solid Set Irrigation

Frost

Frost occurs on clear, cool, calm and relatively dry nights in the spring when temperatures of the air layer near the ground drop below the freezing point. This results in the loss of heat from the leaves, flower and fruit to the open sky (radiation frost).

A second weather phenomena differing from frost is a freeze. This occurs when cool air masses move into the area taking heat from the plant by convection.

Frost rarely causes complete loss because the strawberry plant flowers over a 2 to 3 week period. The first flowers to open are the largest and usually the first to suffer from frost injury. Closed buds are also sensitive to frost damage. Frost losses can range from 20 to 80% depending on the duration of the low temperature and cultivar, vigor, stage of development, and weather preceding the frost.

Frost Control Principle

Water releases heat as it freezes on the plant keeping the plant parts above the freezing point down to about −6.6°C (20°F). At temperatures of −1°C (30°F) at the plant level frost may cause slight injury to the open flowers. Medium injury to open flowers may result at −2°C (28°F). Temperatures below −3°C (26°F) at the plant level will cause severe injury to buds and developing berries.

Note: For steps in frost control see section on the Care of an Established Planting.

Experimental Frost Control Using Less Water

Growers with limited water supplies and poorly drained soils in the U.S. have applied less water at intervals starting at temperatures below 0°C (32°F) with apparent success. This method is based on the theory that the cell salts allow lower temperatures to occur within the cell without causing damage at 1 to 2° lower than air temperatures. This aspect of frost control has not been demonstrated in Manitoba.

Crop-Cooling

Small amounts of irrigated water will cool crops and may lead to better yields. This is because the maximum final enlargement of the fruit can occur only when there is minimum water stress on the plant. Moisture is needed so the cells which are miniature water bags, can fill to capacity. It has been shown that under high transpiration rates water may move out of the fruit into the leaves resulting in lower fruit size and quality. This is a condition called sunscald.

In experiments where small quantities of water were applied frequently during the harvest season in 11 irrigations rather than 2 widely spaced irrigations, berry yield increased from 9.8 to 16.1 tonnes per hectare (4.5-7.2 ton/acre) and the berries were 86% larger. They were more attractive and held longer in storage but they were not as sweet as those produced using 2 irrigations.

Air-conditioning or crop-cooling should be done around noon on hot, dry, days when temperatures reach 30°C (86°F). This lowers the leaf temperature and raises the relative humidity of the air, reducing the transpiration rate and water stress on the plant. The amount of water required for cooling is usually less than is needed for soil irrigation. Plants require small amounts spread over several applications. Generally, rates of 2 millimetres of water per hectare for 2 to 3 hours are sufficient.

Pesticide Injection

Fungicides, herbicides and nematicides which control foliar and soil pests have been applied by irrigation. However, there are no registrations for pesticide injections through irrigation in Canada and this practice is not recommended. Backflow contamination to the water source is a serious danger of this concept. As well, the efficiency of this pesticide application method is questionable.

Fumigation Seals

Soil sterilants such as vorlex, mylone, telone are volatile but can be sealed in the soil with 12 millimetres of water (½ inch) put on immediately after the fumigant is applied. Experimental trials are presently under way in Manitoba using various sterilants and water seal combinations.

New Plantings

Cultivars

The choice of a cultivar depends on:

- the yield potential of the cultivar
- its hardiness
- consumer acceptance

Manitoba's main cultivar is Redcoat. It appears to adapt to a range of soil types, is winter hardy and has the highest yield of the cultivars tested. The list of available cultivars includes:

Everbearing

- not recommended for commercial production
- cost of production per hectare is high with more plants and hand labor required than with other cultivars
- promising day neutral everbearing cultivars from California may offer an opportunity for commercial production. Tests are presently being conducted in Manitoba and Saskatchewan.

Redcoat (Sparkle × Valentine)

- ripens in mid-season
- berries are medium firm, good size, uniform and maintain size well, medium red, very attractive, retain attractiveness after storage. The flavor is only fair
- internal color is light especially if picked prematurely
- plants are strong, runner extensively, are susceptible to verticillium wilt and resistant to mildew
- introduced from Ottawa in 1957

Veestar (Valentine × Sparkle)

- superior in flavor to Redcoat but about 15% lower in yield
- an introduction by Vineland in 1967 which ripens earlier than Redcoat
- fairly productive fruit, medium red, bright, attractive, flesh moderately firm, good size, good flavor, fairly good for processing
- plants fairly vigorous, moderately resistant to verticillium wilt.

Guardsman (Clairabell × Sparkle)

- of value as a late berry for U-Pick operations
- introduced in 1957 from Ottawa
- berries are medium red, should be allowed to color well before picking, very glossy, attractive, firm, highly acid, good for processing, hull more easily than others
- berries from late picking are small but still attractive
- fruit stalks are weak and berries lie close to the ground making it difficult to control rot.

Other Cultivars

- Bounty, Micmac, Protem and Gorella are other cultivars that have been grown in Manitoba. However, they do not compare in yield or general performance with Redcoat. They have selected characteristics that are superior to Redcoat but in general, Redcoat outperforms them.

New Cultivars

Three new cultivars have not been tested in Manitoba but have shown potential in Ontario where they are being tested to replace Redcoat. Growers are cautioned only to try small plantings before adopting the new cultivars for general production. They are:

Veegem (Valentine × Fulton)

- berries have a bright medium red skin, red flesh and are uniform, short, conic in shape, firm and have good size. They are late ripening berries that tend to be small
- superior to Redcoat in firmness, average size, bright red skin color, good uniformity and fresh flavor
- are good or fair as a frozen pack
- plants are vigorous, slightly susceptible to leaf scorch and powdery mildew. They are more susceptible to verticillium wilt than Redcoat and slightly more sensitive to terbacil (sinbar) than Redcoat or Veestar.

Veeglow (Red Glow × Vibrant)

- berries are a large uniform shape, long conical with a slight neck, with bright light red to orange skin and flesh. Berries are firm, have good fresh flavor and make a fairly good frozen pack
- plants are vigorous, runner well
- they are fairly resistant to leaf scorch, slightly susceptible to verticillium wilt and susceptible to powdery mildew. They are fairly tolerant to terbacil (sinbar)
- not as productive as Redcoat

Vantage (Tioga × Veestar)

- this cultivar is five days to a week later than Redcoat, an advantage in extending the picking season
- berries are large, attractive with bright medium red skin, have good flesh color and make a very good frozen pack
- plants are vigorous with good runnering, resistant to verticillium wilt and foliage disease. They are more sensitive to terbacil (sinbar) than Redcoat
- it is not as productive as Redcoat but berry sizes are larger, firmer and more resistant to botrytis rot and have a better flavor than Redcoat or Veestar

Care of Nursery Plants Prior to Planting

Plants will keep in storage at 1.6 to 3.3°C (35-38°F) for up

to two weeks. Do not refreeze plants that have initiated any growth. Once the temperature rises above this level, rot and drying occur more quickly. Temperatures of 4.4 to 10°C (40-55°F) can be used temporarily, provided the plants are checked for mold frequently. Take plants out of cold storage the day of planting and cover plants with a tarp when on the truck. During planting the plants should be wetted to keep the roots from drying out. Plant crates should be put in the shade with wetted burlap bags thrown over them. A cool cloudy day is preferred to a hot, sunny, windy day for planting.

In the event that planting must be delayed and cold storage facilities are unavailable, keep plants in a well-drained location sheltered from the sun and wind. Plant bundles should be separated and put in a shallow V-shaped trough, spreading out the roots, and ensuring the crowns are covered at ground level. Soil should be slightly firmed around the roots and the plants left in this condition until the field is ready for planting.

Soil Preparation

Once the planting site has been selected, it needs proper preparation, which generally takes 2 years. Land preparation is critical in terms of soil tilth and perennial and annual weed control. Soil preparation has three main objectives:

1. To destroy as many weeds as possible, especially perennials such as thistle and quackgrass. The field must be clean. Growers attempting to shortcut this basic production rule may have a never ending battle controlling weeds. Where these weeds require chemical control your agricultural representative or weed supervisor should be contacted for recommendations on chemicals and procedures.

2. To add as much organic material as possible. A good recommendation for strawberry production is the soil incorporation of well rotted barnyard manure or a green manure crop a year before planting. The organic matter helps to improve soil tilth, overall structure and water retention.

Another important feature is the inoculation of beneficial soil bacteria and the slow release reservoir of nitrogen and trace elements. Green manure crops such as rye used at the rate of 125 kilograms/hectare (2 bu/acre) or buckwheat at 81 kilograms/hectare (1½ bu/acre) could be used. The crops should be well fertilized using 56 kilograms/hectare (50 lbs/acre) of actual nitrogen so as to leave the field in as fertile a condition as possible for the strawberries that are to follow.

Green manure management includes sowing the crop as early as possible and to plow it under in late summer to allow time for the incorporated crop to break down in the soil. At least 40 tonnes/hectare (18 tons/acre) or more of barnyard manure can be used to advantage. Well rotted manure may be incorporated in the spring the year before planting to permit the straw to break down. Apply poultry manure well ahead of planting at a maximum of 11 tonnes/hectare (5 tons/acre). Poultry manure can burn strawberry roots. (See Table 3)

3. To have organic matter well decomposed and the field in proper tilth at planting time. Before planting work the soil deep enough to get a deep and reasonably loose planting bed. This can be done by using a rotor tiller. At this time, the soil insecticides such as chlordane as well as fertilizers are incorporated into the soil. Some growers have found that plants grow better if placed in the soil that has not been disturbed in the spring (moisture reserve).

Table 3 Plant Nutrient Value of Manures

		Kg/Tonne of Manure			lbs/Ton of Manure		
Type of Manure	Quality	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Cow Manure	Good	2.5	1.5	4	5	3	8
	Poor	1.0	0.5	3	2	1	6
Poultry Manure	Good	5.0	3.0	4	10	6	8
	Poor	3.0	2.0	3	6	4	6

Fertilizer Recommendation Before Planting

Apply and incorporate the fertilizer as recommended by the soil test. Pay close attention to phosphorus content. Depending on the fertilizer type used, sulphur may or may not be included in the mix.

Planting and Plant Spacing

Always buy certified plants when starting a new planting. Nursery stock quality has a direct bearing on the plant's eventual performance and yield.

Through bulk buying and cold storage, the Manitoba Strawberry Growers' Association imports certified plants from other provinces. This reduces the cost for the individual and helps reduce the plant spoilage.

Plant as early in the spring as possible. However avoid wet soils, as this will result in poorly set plants. Certified plants cannot be expected to perform at their best with improper handling and poor conditions after planting.

Short rows make thorough picking easier. The use of aisle way rows provides longer rows for easier cultivation and management practices. It also permits the long rows to be divided for easier customer picking. Generally do not develop a row greater than 10 sprinkler head spacings or approximately 122 metres (400 ft) long. Align rows for efficient layout of irrigation pipes. Plant rows so that they fall within the irrigation spray pattern. Avoid planting too close to shelterbelts because of shading and moisture and nutrient competition.

Manitoba growers that have their rows from 1.2-1.5 metres (4-5 ft) apart, should set plants about 0.46 metres (18 inches) apart in the row. The Manitoba growing season is short and closer planting in the row helps to establish a full matted row the first year.

High density planting where spacing is kept to 0.9 to 1.06 metres (3-3½ ft) between the rows and 8-25 centimetres (3-10 inches) between plants is being adopted in the mid United States. The rows are very narrow with a high density of mother plants compared to daughter plants. Apparently the fruit picked in the first year more than compensates for the extra cost of the certified plants in the establishment year. Trials are underway to examine the yield and the economic potential of this practice in Manitoba. Growers could experiment with this approach on a small scale.

In Ontario, using the double-hill system, plants are spaced 30.5 centimetres (12 inches) apart and 76 centimetres (30 inches) between rows. About 49,400 plants/hectare (20,000 plants/acre) are used. This approach has not been as successful as the matted row system. The advantages of earlier ripening and larger berry sizes are offset by the cost of runner removal and the extra cost of plants per area.

If the width of the picking row is kept at 30 to 40 centimetres (12-18 inches) a planting distance of 0.9-1.06 metres (3-3½ feet) between rows can be used. For a picking row of 64-76 centimetres (24-30 inches) a row distance of 1.2-1.4 metres (4-4½ feet) is required. (See Table 4)

Table 4 The Number of Plants Per Hectare (Acre) Required at Various In-Row & Between Row Spacings

Spacing In the Row (metres)	Between the Rows (metres)	Approx. No. of Plants/ha	Spacing In the Rows (ft)	Between the Rows (ft)	Approx. No. of Plants per acre
.076	1.07	123,001	.25	3.5	49,783
.15	1.07	62,305	.5	3.5	24,891
.24	1.07	38,941	.8	3.5	15,557
.3	1.07	31,153	1	3.5	12,446
.46	0.9	24,420	1.5	3	9,680
.46	1.07	20,317	1.5	3.5	8,297
.46	1.2	17,819	1.5	4	7,260
.61	0.9	18,015	2	3	7,260
.61	1.07	15,321	2	3.5	6,223
.61	1.2	13,437	2	4	5,445
.76	0.9	14,459	2.5	3	5,808

To determine the number of plants required, multiply the distance between the rows by the distance of the plants within the row. Divide the resulting square area into the area — 10,000 square metres for a hectare or 43,560 square feet for an acre.

Example

- distance in the row 0.76 m
- distance between the row 1.07 m
- the square area equals: $0.76 \times 1.07\ m^2$
- Total number of plants/hectare

$$\frac{10,000}{0.76 \times 1.07} = 123,457$$

Example

- distance in the row 0.25 ft
- distance between the rows 3.5 ft
- the square area equals: $0.25 \times 3.5\ ft^2$
- Total number of plants/acre

$$\frac{43,560}{0.25 \times 3.5} = 49,783$$

Starter Solutions

Fertilizers high in phosphorus such as 10-52-17 or 10-30-10 are sometimes added to the transplant water during planting. Dissolve 0.5 kilograms in 455 litres (1 lb in 100 gals) of water to give about 0.14 litres (one cup) per plant. Some mechanical planters automatically give a "shot" of starter solution to each plant. Many growers find that when they have supplied the needed nutrients in the pre-plant application of fertilizer, water alone is sufficient.

Planting Depth

A plant should be set so that the mid-point of the crown is at the level of the soil surface. (Figure 12). If set too deep it may be damaged by rot so that runnering will be delayed and reduced. If set too shallow the crown and tops of the roots dry out.

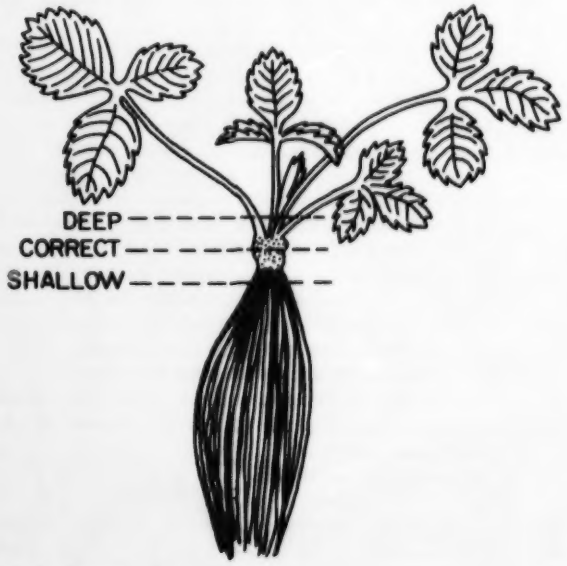


Fig. 12 Correct planting depth.

Most plants are machine planted. Set the machine so that the plant roots go straight down and not on a slant. When roots are longer than 15 centimetres (6 inches), they may be trimmed.

Avoid planting bundles of plants that have grey mold on the roots when unpacked. Discard these, especially if the mold is confined to the upper root and lower crown area.

One Manitoba grower has developed a packer made of 2 rubber wheels inclined towards each other. This packer is attached to the tractor that follows the planter, and firms the soil tightly around the roots. Another innovation is an all terrain balloon-tired tricycle which is driven over the rows with its middle tire. The wide low-pressure tire is ideal for firming the soil around the new transplants without causing damage.

Always have someone follow the transplanter to check planting depth and to reset any plants not properly planted. A small "shot" of water or soluble fertilizer solution at the time of transplanting is beneficial under certain spring conditions. Do not apply too much water, otherwise the roots will float up before being covered with soil creating a "J-root" system as opposed to a properly fanned-out root system.

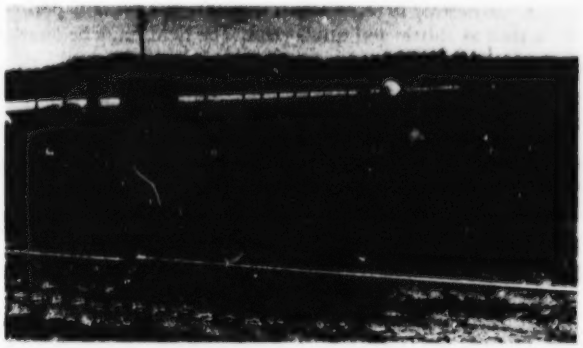


Photo 6 — Planting strawberries.

Care of the Young Planting

The whole life of the planting and especially the yield of the first bearing year depends on the good establishment of a fully matted row in the planting year.

As soon as the new plants begin blossoming, remove the flower stalk. It may be necessary to go over the field 2 or 3 times. De-blooming results in earlier and increased runnering plus a more developed root system. This is important since early formed runners bear most of the fruit the following year.

Blossoms may be left on the first year and harvested in high density plantings, reducing the extra cost of the plants.

The years before planting are important for eradicating perennial weeds. Avoid chemical weed control until the plants are fully established, usually 4 to 6 weeks. Judgement must be used to ensure the planting is vigorous before herbicides are used in the establishment year.

During this time cultivation and hand weeding is necessary. Cultivation should be shallow, 2.5-5 centimetres (1-2 inches) in depth. Try to cultivate in one direction so that the runners set well. Remove any loosened soil that has flipped up on to the plants. Hand hoe to remove weeds not reached with the cultivator. Recommendations are released annually by Manitoba Agriculture in the *Guide to Chemical Weed Control*.

Follow recommended directions closely and use only chemicals cleared for strawberry use in Manitoba. Also keep in mind the residual effect of some strawberry herbicides, especially on lighter soils and their effect on certain strawberry cultivars.

Fertilization After Planting

Fast development and early runnering is the key to maximum production. Plants that grow slowly with small light green leaves require more nitrogen. To correct this, side dress plants with 17-22 kilograms/hectare (15-20 lb/acre) of actual nitrogen or place it directly on the row. Repeat this one month later if no response is shown by the first application. It is also important to establish strong plants by early fall in order to allow for blossom bud formation for next year's crop.

If the fertilizer is broadcast or placed directly on the row, ensure that the foliage is dry and brush all fertilizer pellets off the plants by dragging burlap or a rope behind the applicator.

In late August, apply 28-56 kilograms/hectare (25-50 lbs/acre) of actual nitrogen to help fruit bud formation. Use a complete fertilizer containing this amount of nitrogen if soil tests so indicate.

Spray Program

New plantings are prone to insect and disease attack especially if the fields are adjacent to established strawberry plantings. Spray programs should be followed according to the annual recommended strawberry spray schedule for strawberries published by Manitoba Agriculture.

Placement of Runners

The special care given to an establishing planting will pay handsome dividends in the bearing year.

Early hand set primary runners will out yield secondary and tertiary runners 14 to 1. Quaternary runners usually do not root deep enough to develop significantly by the end of the season.

Once the row is full, the extra runners may be cut off by a rolling colter attached to the cultivator. In high density plants primary and secondary runners could be set at 30 centimetres (12 inches) spacing or greater. The plantation needs frequent irrigation at runnering time. Only if the soil is moist will the runners make sufficient root and top growth before the end of the season.

Irrigation of a Young Planting

Maintaining a uniform moisture level in the soil at planting time and during the initial establishment period is important for rapid plant development. Care must also be exercised not to maintain too high a percentage of soil saturation with the irrigation system in order to avoid over saturation due to natural rainfall levels. During runnering a soil moisture level should be at least 75% of that of field capacity 1 to 1.5 centimetres (.4-.5 inch) below the soil surface in order to facilitate rapid daughter plant rooting.

Mulching

Mulching is a form of crop protection used to prevent injury to crowns and roots from low temperatures. It keeps soil temperatures more uniform and prevents plants from drying out from cold, dry winds and it helps to trap snow if properly applied. If mulch removal is delayed, blooming can be set back several days. Moving the mulch between the rows in the spring helps keep berries clean. Moisture is conserved and weeds are depressed. In addition mulch makes picking more pleasant.

It is good practice to apply a herbicide to the plants just before mulching. Herbicides recommended are described in the *Guide to Chemical Weed Control*. The herbicide should give weed control in spring and keep volunteer grain from sprouting. Use only fresh dry straw which will lie loose and fluffy, providing a good insulation layer to the strawberries.

Wheat and oat straw have been found to be the best mulch material in Manitoba. Use straw from grain fields that are as weed free as possible. From 4.5-6.7 tonnes/hectare (2-3 tons/acre) (120 small bales) are required. The mulch layer should be 5-8 centimetres (2-3 inches) thick on settling. A good straw spreader will apply an even cover over the entire area and will not chop the straw into short lengths. The straw should be sticking up, not flat like in a swath, so it can trap the snow. Exposed sites not properly sheltered may have problems maintaining straw cover.

Many growers have built their own straw spreaders, greatly reducing equipment costs. A new straw spreader applicator called the bale buster can handle large bales reducing the labor input from three persons to one person.

Apply the mulch on a calm day but avoid heavy applications. High slug populations have been associated with overmulching. Locations where the mulch is prone to being blown off by winds may be wetted by irrigation slightly to weight the straw into place.

Trials are presently under way to determine the use of plastic mulch as a substitute for straw.

Cover the plants once they are hardened off (become dormant) by several sharp frosty nights but before temperatures drop below $-6.7°C$ ($20°F$). Serious winter injury can occur if dormant plants are not covered early enough in the fall.

Care of an Established Planting (Picking-Year-End)

Mulch Removal

Remove any mulch in the spring before new leaf growth begins and when the leaves become light yellow. Normally, this happens during the first two weeks of May. Remove earlier if the soil is wet. A side delivery rake may be used to remove the excess straw from the rows in the aisle. Rotary mowers have been used by some growers as an excellent way of removing the straw. The blade's suction moves the excess straw into the aisles. To do a good job, go over the rows twice. Partial removal of the mulch delays maturity without harming plant growth. This practice can delay blossom development and avert early frost damage to mature blossoms.

Spray Program for the Picking Year

The key to successful pest control is a timely spray program. Growers should inspect their fields periodically, become familiar with the life cycle of strawberry pests and how to detect their presence. For example, many pests overwinter in leaf litter in the row and start their activity even before the straw is removed. Winter injured or stressed plants appear to be more prone to attack by insects and disease and therefore require more inspection than healthy stands.

The tarnished plant bug, strawberry weevil or strawberry clipper can cause serious reductions in yield by damaging the fruit.

Spring Fertilizer Applications

Apply up to 11 kilogram/hectare (10 lbs/acre) of nitrogen to bearing fields after the flower buds have started to form. Early application of nitrogen may result in overly vigorous leaf canopies, interfering with pollination and fruit quality.

Pollination

Deformed berries are caused by:

- slight frost injury to blossoms
- uncontrolled tarnished plant bugs (they also cause hard ends)
- a lack of proper pollination

Strawberries are self-pollinated. The action of wind shaking the fruit stem helps to pollinate the flower. Native insects, too, are useful. Also it is helpful to have bee colonies in the fields. Two colonies per hectare (one per acre) are recommended. As insecticide sprays are toxic to bees it is necessary to spray fields late in the evening when the bees are less active.

Steps to Control Frost

You need a thermal alarm, automatic alarm — probe sensors located in the flower bud and 2 accurate thermometers. One thermometer should be placed in the mulch or at the crop level in the field. Locate the other beyond the frost protection irrigation system.

A comparison of these two readings will help you decide when to stop the system.

Start the sprinklers just before the air temperature at ground level reaches 0°C (32°F). Don't expect ice to form immediately. Leave the sprinklers on until the temperature increases enough to start melting the ice that has formed. Do not stop when the ice begins to form on the plants.

The time needed to control frost varies from 3 to 15 hours, but on average it takes 8 to 10 hours.

A slight breeze or cloud cover during the night may temporarily raise the temperature above the freezing point. But the temperature can drop below freezing just as quickly if conditions change again.

Apply 2.5 to 3 millimetres of water per hour (1/10-1/8 inch/hour). At this rate 655 to 822 litres of water per hectare (60-75 gal/acre) is being applied.

Ice may form up to 1.6 to 12 millimetres thick (1/16/1/2 inch) depending on the intensity and duration of the frost. But this does not seem to affect the low growing strawberry plants.

Symptoms of Frost Damage

On frost damaged plants the center of the flower is blackened while the petals and leaves appear uninjured. This blackening occurs a few hours to one day after the frost. Frost can also damage the developing fruit, deforming the berries.

Renovation

Renovation is done to keep a planting for an additional crop year. Once the last picking is over, fields should be immediately renewed or renovated since Manitoba has a short fall season. A week lost here may well mean a greatly reduced crop the following year.

Since it costs much less to renovate a planting than to establish a new one, some growers keep a planting for 3 to 4 years, some even longer. Renovation is most successful if plants are vigorous. Strawberry plants tend to enter a stage of low activity toward the end of harvest but renovation stimulates renewed growth. It also eliminates weak plants which only compete for fertilizer and moisture.

How to Renovate

1. Apply 560 kilograms per hectare (500 lbs/acre) of 10-10-10 or 336 kilograms per hectare (300 lbs/acre) of 17-17-17 directly over the rows.

2. Mow the tops of the plants 2.5-5 centimetres (1-2 inches) above the crowns. A properly set rotary mower is an excellent way to do this. Set the mower at a height so that the old leaves are removed but not the new expanding leaves.

3. Rake unrooted runners and weakly rooted plants into the aisle so the plants don't get too thick. Ideally, the plants should be 15-23 centimetres (6-9 inches) apart.

4. Cultivate or rotor till the aisles. A 46-61 centimetre (18-24 inch) row is generally considered best. If the row is very thick in growth, narrow it to 46 centimetres (18 inches).

5. Apply recommended herbicides. Some hand work may be necessary to remove tall weeds that have established.

6. Irrigate well and repeat as necessary.

The herbicide will control most of the weeds. Hand weed escaped weeds if necessary to keep the field completely clean. Apply nitrogen early to mid-August. Mulch for winter protection in mid to late October.

Fertilizer Application at Renovation

After the last picking and before mowing, apply 56 kilograms per hectare (50 lbs/acre) of actual nitrogen using a 1-1-1 fertilizer such as 10-10-10 or 17-17-17. Apply 10-10-10 at 560 kilograms per hectare (500 lbs/acre) or 17-17-17 at 336 kilograms per hectare (300 lbs/acre). This could be followed by a 28 kilogram per hectare (25 lbs/acre) application of actual nitrogen in mid-August.

U-Pick Harvesting

In Manitoba most strawberries are harvested on a U-Pick basis. This overcomes the problems and cost of labor, buying containers, handling, grading, storage and shipping. In a U-Pick operation it is important to have a high quality, high yielding product for the customer. Through surveys, repeat customers have rated factors such as neatness and cleanliness of the fields, freedom from weeds, diseases and insects as important. A number of requirements are essential to the success of a U-Pick operation:

- A location on or near an all-weather road. This is most desirable as customers should be able to get close to a picking area.
- Adequate parking areas and in the case of larger operations, a parking attendant.
- A way of informing people of the location and the exact time of picking. Growers would do well to have personalized business cards made up. A map showing how to get to the strawberry farm can be printed on the back of the card.
- A telephone or two is essential. A partyline phone is not adequate.

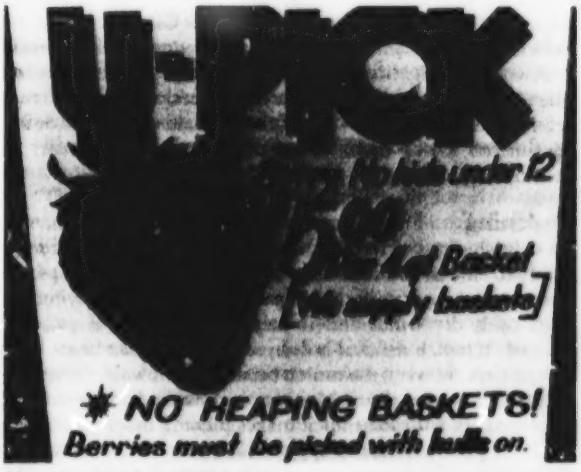


Photo 8 — Strawberry U-Pick sign.

Photo 7 — Customers at a U-Pick farm.

Drawing Customers

A satisified customer is the most effective advertisement for a U-Pick operation. Good picking, fast checkout, fair pricing and friendly staff all contribute to good customer relations. Lineups, being turned away because of lack of crop, and poor picking discourage the customer. Attractive directional U-Pick signs are important to create a good first impression. The Strawberry Growers' Association has designed and made available U-Pick signs for its membership at a reasonable cost.

The Strawberry Growers' Association in co-operation with Manitoba Agriculture annually print U-Pick Berry Brochures. The "Do's and Don'ts" of U-Pick procedures are listed for customers along with other helpful tips and recipes. The association also prints a map and list of U-Pick strawberry growers.

Liability

Growers should be sure their insurance policies adequately cover U-Pick operations. Fence out dugout areas and post signs warning of potential hazards. Exercise extreme caution with pesticides on crops prior to harvest. Strictly follow recommended dosages and waiting days to harvest since many customers and young children are eating the unwashed fruit in the field.

Time to Pick

Half green berries are not full weight or size. Berries weigh more and are larger when ripe. Have berries picked only where there is an adequate number of ripe berries. The season determines the number of times a field is picked on a weekly basis. Since very hot weather ripens the fruit faster, picking every two days may be required. On the other hand, cool weather holds back ripening so that picking takes place every three days. Encouraging pickers to select fully ripened berries increases the return based on size. There is a 76% increase in size from the white berry stage to the fully red stage.

The Picking Operation

Every operation should have a picking booth or sales shed. Place a bulletin board with price information in a prominent location. This makes customer checkout faster. Most growers welcome children but pets are never allowed. Customers come to the booth for directions to picking locations and have containers weighed or processed. Fields should be set out in numbered rows. Have someone in the field supervising and helping customers to find the right row. Booths need to be adequately staffed in order to avoid lineups. A rule of thumb is to have approximately 1 field supervisor for 40 U-Pick customers.

Many growers are selling berries by volume. A 4 litre basket is become the standard. Customers may also bring their own 4 litre ice cream pails. However, berries should never be picked into a plastic pail then dumped into another container. This causes unnecessary bruising of the tender fruit. This process also is time consuming and creates bottlenecks in the checkout. Much of the fruit travels a considerable distance in hot car trunks and it keeps better in a shallow cardboard container.

Sales Etiquette

People who meet the customers should be friendly, helpful and patient. Fair and friendly treatment is the best way of getting the customers to return. Goodwill should be the byword of every U-Pick operation.

Sale of Picked Berries

When growers pick the berries themselves or have them picked for sale it is necessary to provide a properly graded product. Pickers should be given instructions for picking berries.

Amenities

It is important that washroom or toilet facilities are available. These will generally be outhouses. Be sure they are clean, painted, disinfected and properly maintained. It is important to locate these facilities well away from the picking area. A hand washing stand should also be provided. Many people consider a pick your own trip as a fun day which may include a picnic. It is worthwhile setting aside a shady area and even supplying some tables. Play areas, sandboxes and swings for children could be added. Soft drink dispensing machines are an asset. Extras like these make the customer's visit a happy experience and the goodwill pays off handsomely.

Equipment for Strawberry Growers

Growers should be careful in equipment selection and purchase. Consult other growers for a comparison of make and model performance and general characteristics. Keep in mind equipment flexibility. Can it be used in an expanded acreage or will new equipment be needed? For example, growers considering high density planting, closer than 30 cm spacing in the row (12 inch), should consider a "disc planter" instead of a "finger planter".

Tractor

Select a 35 hp tractor capable of powering a rotor tiller or a smaller four wheel drive unit. Too large a unit will contribute to soil compaction and maneuvering problems.

Equipment

- planter
- sprayer capable of delivering 455 litres/0.5 hectares (100 gal/acre) at least 1 379 kilopascals (200 psi) pressure capability
- rotor tiller
- straw spreader
- irrigation equipment
- pipe trailer
- fertilizer spreader
- soil sub-soiler (optional)
- frost alarm

Pesticide Safety and Management

In selecting pesticides for crop management consider these factors:

Toxicity of the Chemicals — Chemicals containing a high LD_{50} rating are less hazardous to the farmer and the environment. For example, malathion which has a high LD_{50} rating of 1200 is not as toxic as guthion which has a low LD_{50} rating of 7.

Use of Registered Chemicals — Use only chemicals registered for use on strawberries. Follow the label rates and day waiting periods to harvest. Failure to follow this basic rule of pesticide safety exposes the grower to undue liability.

Proper Safety Equipment — Protective devices such as rubber gloves, a recommended respirator, and other clothing should be used when handling pesticides. Pesticides affect individuals differently. They can enter the body through the mouth (orally), through the skin (dermally), or through the lungs (respiratory system).

Poisoning — Be aware of what to do in the event of a spill, or an accidental poisoning. Procedures should be reviewed prior to handling a pesticide. Proper storage and disposal of these materials is important especially where children of U-Pick customers may be accidentally exposed to them.

Chemical Application — Pesticide application through the irrigation system is not a recommended practice as coverage is not efficient. Most pesticides used in this application method are not registered for this use. As well, there is a danger of water supply contamination with a sudden drop in mainline pressure. Contamination of the water supply by back siphoning can be avoided by using a reduced pressure back flow preventer. This is installed in the supply line at the point well ahead of where the fertilizer is to be injected into the system.

NOTE: Consult the Agri-Water Branch, Manitoba Agriculture regarding local regulations before installing this unit.

Similar precautions should be observed when filling sprayers from lakes, rivers or streams. Insure that anti-siphon check valves are used.

Wait at least 24 hours or the waiting period specified on the label before entering treated areas for further management practices, such as hand weeding and thinning. Chemical contamination on the foliage can be absorbed through the skin or lungs of workers if caution is not observed in waiting the prescribed time.

Spraying Effectiveness — A number of factors influence the success of spraying for pests or diseases. These include the incorrect diagnosis of the problem, too long a spray interval, resistance of the pest or disease, weather conditions, or the pH of the water (a high pH of 8 or greater can affect the efficiency of certain pesticides).

High pressures are essential for full coverage on the large foliage area of a strawberry row. Use of a chain ruffler in preference to a solid bar has been shown to improve the action of the sprayer. Better coverage to the upper surface of the leaf and twice the coverage is also achieved by setting the nozzles to the rear of the chain rather than in front of it and also by pointing the nozzles slightly forward. Chemicals used must get to the source of potential trouble. At least 1 123 litres/hectare (100 gals/acre) and pressures of 1 380 kilopascals (200 psi) are necessary for good coverage. Field sprayers with low volume and low pressure are virtually useless for spraying insecticides and fungicides.

Strawberry Problems

The ability to recognize and correct production problems early and before significant yield reduction can take place is essential for successful strawberry production. Shortcuts in preparing and maintaining a strawberry field are often a cause of serious pest problems later in the production cycle. Frequent field inspections (perhaps daily during the production cycle) are recommended for early detection of problems.

Identification

Knowing the habit and damage characteristics of a disease or insect is essential to identify field problems. For example, wilting of new leaves in the crown is an indication of early cutworm damage. Quick action at this stage results in minimal damage to the plants.

However, in some pest cases, observation of tell tale damage will not provide early enough warning for corrective action. For example, damaged berry ends or nubbins are usually caused by the tarnished plant bug. The damage usually occurs when the fruit is in its early undeveloped stage and it is difficult to detect. Injury to the fruit becomes evident after the insect has left the blossom. Corrective measures at this stage are difficult and ineffective. Maintaining a regular spray program gives additive measures of insurance for those insects that may be missed on field inspections.

Complimenting inspection with timely pesticide application is a good management practice. Weak stands of strawberries are more prone to insect and disease attack. Excessive use of mulch and poor maintenance of headland weeds growing near strawberry fields favor slug populations. Although the direct damage to the fruits and plants can be minimal, serious damage is caused by the customer's image of your field. Finding slugs among plants is an unpleasant experience for U-Pick customers.

Environmental Problems

There are a number of environmental problems for strawberry plants which are not caused by insect or disease. These include:

Tipburn of Strawberry Leaves — This problem occurs during hot days and cool nights in young strawberry stands. The new plants are slightly malformed and show dry leaf margins. This condition is generally found to be temporary. This condition can also occur after a frost to young unfolding leaves.

Yellowing — This yellowing condition affects the foliage. Certain cultivars appear more prone to it than others. A range of factors, from genetic to alkaline soils and topography contribute to yellowing. In some severe cases the yellowing can be corrected by using an iron chelate soil incorporated at the rate of 14.29 kilograms/hectare (13 lbs/acre) actual iron. Work is being conducted to determine a less expensive corrective measure.

Root Disease Organisms — Weak stand vigor may be caused by a delayed winter injury or buildup of root disease organisms. Small leaves and slow response to fertilizers indicate some root damage.

Growers not familiar with a problem can contact the Manitoba Agriculture Fruit Crop Specialist by telephoning 1-944-3831 or toll free 1-800-282-8060. Depending on the nature of the problem and its urgency, diagnosis and recommendations can be made by phone, examining mailed in samples or on-site visits.

Disease and Insect Control

The Manitoba Agriculture publication, *Strawberry Spray Recommendations*, aids growers in controlling insects and diseases. The timing of control is important as the program is designed to prevent insect or disease injury. For success, it is important to make all the applications at the time recommended.

Weedy borders around the strawberry field are not only a source of weed infestation but can also harbor insects, diseases and slugs. Weeds in the borders should be cut and occasionally sprayed with insecticides.

Insect control begins when a field is prepared for planting and a soil insecticide is incorporated. Disease control starts with the purchase of certified strawberry plants. Certified plants are as free from disease as possible. The disease and insect control program continues by following the recommendations of the spray calendar.

The grower will examine all his fields for possible trouble. Any off-type plant should be pulled, examined and removed from the field. Early detection of insect infestation and a selective spray program could help a grower save a crop. If necessary, call the Provincial Entomologist or the Fruit Crop Specialist for assistance.

Remedial sprays may possibly save a crop. However, this is not feasible if the strawberries are ready for picking. Disease and insects result in a drain on the vigor of a strawberry stand. Follow the Spray Recommendations to avoid large buildups of disease and insects which reduce vigor. Most pesticide schedules work on the principle of prevention rather than corrective measures.

Strawberry Pests

Pests That Attack Leaves

Strawberry Leaf Roller — In the early stages, the larva of this moth may feed on either side of the leaf. Often, two adjacent leaflets are tied together. Damage is usually more common on new plantings late in the season. Leaf rollers are very susceptible to attack by several parasites. Because of this, populations are usually kept at such low levels that chemicals are not needed for their control.

Aphids — Several kinds of aphids occur on the underside of leaves of the stem. They are small, soft-bodied and usually green or yellow. They seldom cause much direct injury, but some are very important because they transmit virus diseases.

Cyclamen Mite — This mite is so small that it is scarcely visible to the naked eye. It is mainly a pest on greenhouse plants but has caused serious losses to strawberry plantings.

The cyclamen mite feeds on the young unfolding leaves in the crown of the plant. As a result, leaves appear stunted, crinkled and malformed when they emerge. Later the mite feeds on the blossoms causing a distortion of the fruits. Under high population feeding which can occur during hot, dry weather, flower stalks are short and thick leading to blossom distortion and fruit abortion. After the mite becomes established, it is hard to control. In setting a new planting it is important to use plants free of mites.

The adults overwinter in the crown of strawberries. Their populations can increase very quickly in the spring by as much as one generation in 10 days under good temperature conditions.

Pests that Attack the Blossoms or Fruit

Tarnished Plant Bugs — Plant bugs cause small, deformed berries or "nubbins". This injury results when the bugs puncture the blossoms of young fruits. It is often mistaken for damage by frost or imperfect pollination. High populations of bugs, which are seldom noticed, can cause severe loss of fruit quality and yield. The insect is small and green in the early nymphal stage. At this stage the nymphs feed on the blossoms causing nubbins or deformed fruit.

Adults are somewhat flat, level and oval in shape, 0.6 centimetre (0.25 inch) with a mottled brown or bronze coloration. The adults fly when disturbed.

Adults overwinter in plant debris, laying their eggs on the plant stems in the spring. The young hatch and then feed on the young developing blossoms and fruit.

Strawberry Weevil — This dark reddish-brown weevil is about 0.25 centimetre (1/10 inch) long with the head prolonged into a slender, curved snout about half as long as the body. This is known as the "Strawberry Clipper" or simply the "Clipper" because of the habit of clipping buds.

The beetles leave their winter quarters in fence rows and woodlands about the time the first strawberry blossoms appear. Eggs are deposited in the opening blossoms or in the buds which are nearly mature. The stem of the bud is then cut so that it hangs by a mere thread or falls to the ground. In about one week, the eggs hatch into white, legless grubs. The larva develops inside the bud and reaches maturity in 3-4 weeks.

Adult weevils appear in early summer. After feeding on the pollen of various flowers for a short time, they seek hibernating sites until the next spring. Only one brood appears each year. Injury is most likely to occur when strawberries are grown adjacent to woodlands or other suitable hibernating quarters.

This weevil also attacks raspberries.

Cutworms — These voracious caterpillars are non-selective in appetite and may appear at any time during the growing season. Young plants are occasionally damaged by cutworms which cut them off at the soil surface. On older plants, they feed on the leaves but cause insignificant damage unless they are very abundant. The greatest damage results from their feeding on ripe fruit and making large holes in the berries.

These stout caterpillars are nearly 2.5-3.7 centimetres (1-1½ inches) long and are striped, mottled, or dingy gray. They are seldom observed in the fields since they usually feed at night. During the day they burrow down into the soil or hide beneath plant debris on the ground.

Most cutworms attacking strawberries overwinter as partially grown caterpillars in strawberry fields. Cutworms become active early in the spring. As the weather warms, they reach full growth and pupate in the soil. The moths are brownish or grayish and are active only at night. Several generations occur each year.

Cutworms eat large holes in the fruit of strawberries. These holes are larger than those made by leaf rollers and no slime occurs as in the case of slugs. Since each cutworm feeds on a number of berries, the damaged fruit tends to be concentrated in localized areas.

A recent cutworm problem has been identified as the strawberry cutworm *Amphipoea interoceanica* (Smith). Eggs are laid in August on dead strawberry leaves and hatch in early May. Young larva feed in the leaf stalks. Older larva bore into the crowns and kill the plants. The plants are first attacked in the second year of growth and by the fifth year the entire crop may be lost. Older plants appear to be more prone to this pest attack. Early detection is important so the proper corrective sprays can be used in time for harvest on a bearing field.

Slugs — Can cause considerable damage to the public image of the U-Pick operation. High slug populations have been associated with poorly maintained shelterbelt and headland areas adjacent to strawberry fields. Fields adjacent to riverbanks or creeks have also been shown to harbor high levels of these pests. The over use of straw mulch can result in a mat of moist decaying material of which the lower level favors slug populations. Timely sprays and good sanitation of shelterbelt and headlands will control this pest.

Strawberry Diseases

Diseases Attacking the Leaves

Leaf Scorch — This fungus, *Diplocarpon earliana* (Ell. & Ev.) Wolf, causes many purple blotches up to 0.6 centimetres (0.25 inch) in diameter. The centers of the blotches become brownish but not gray or white as in the case of leaf spot. Badly affected leaves dry up, their margins curl downward and assume a burnt or scorched appearance. The calyxes, petioles, stolons and fruit stalks may be severely attacked. Unlike leaf spot, leaf scorch attacks leaves and plants in all stages of growth. Serious infections may occur during wet spring months. Leaf scorch is spread by rain and handling in the same manner as leaf spot.

Leaf Spot — Mycosphaerella fragariae — (Tul.) Lindau, known as the casual fungus, causes this disease. It first appears on the leaves as purplish spots that resembles leaf scorch. Later these spots enlarge to a diameter of 0.3-0.6 centimetre (0.125-0.25 inch). The centers become gray or white with reddish to purplish borders. Leaf petioles or stalks, fruit stalks, stolons (runners) and, to some extent the calyxes (caps or hulls) may be attacked. Plants and leaves are most susceptible early in the growing season and in late summer, especially where growth is very succulent. The leaf spot fungus may attack the fruit and cause black seed. The spores of the fungus are formed on the spots and are spread by rain or by hands, tools or clothing, when plants are wet.

Powdery Mildew — This fungus *Sphaerotheca macularis* (Wallr. ex. Fr.) Magn. affects all the above ground plant parts. Leaves, calyxes of flowers, and fruit support growth of mildew. Infected leaves curl upward, become reddish on the underside and, in severe instances, develop badly burned areas at the margin. A white, powdery fungus growth may be seen on the underside of severly infected leaves. Powdery mildew develops in the spring and fall when conditions are usually most favorable.

In the spring, it begins soon after plant growth starts. Its gradual spread may not be noticed until most of the plants in the field are affected. If a severe outbreak occurs before picking, the crop may be greatly reduced. Symptoms are most noticeable on warm, dry days.

Diseases Attacking the Fruit

By far the most important diseases of strawberries are the fruit rots caused by several fungi. They are capable of ruining a large portion of the crop. Losses from fruit rot are very obvious because it destroys the finished product. Picking and packing are more costly when rots are present in the field. Losses from fruit rots vary from year to year and from locality to locality according to weather conditions prevailing from first bloom through harvest.

Gray mold — The causal fungus *Botrytis cinerea (Pers)* is very common and often causes serious losses in strawberries. It affects blossoms and blossom stalks and green or ripe fruit. Infections usually start in the blossoms and may destroy the entire blossom stalk. Blossom infections may proceed only as far as the calyx or hull where the fungus can remain dormant until the fruit begins to ripen. Then it is reactivated to cause fruit rot.

On the fruit the rot is rather soft and light brown in color. The fungus may spread directly to the berries that are in contact with rotted berries or by spores (seeds) of the fungus that are blown on or splashed on the blossoms or berries. The fine gray powdery growth of the fungus develops on infected blossoms, fruit stalks, fruit and other infected parts. The fruit rot and gray mold may not appear on the ripe fruit until one or two days after the berries are picked. Shade or dense foliage in the bed and extended periods of excessive moisture favor the disease. Any factor that produces soft fruit favors fruit rot development. Customers usually complain of off-flavor berries if they are eaten.

Slime Mold — This fungus is considered a non-parasitic fungus of strawberries, that is it just uses the strawberry plant and the plant parts as a structure to support itself. It is usually evident as a white to black mass of ash like material, late in the picking season or during renovation. Occasionally during a later picking season or on later cultivars, this mold will spread from the leaves and appear on the fruit as white specks that resemble insect eggs. The cycle of the pest is not well understood and no fungicide is recommended to date. Work is being conducted to obtain more information on the fungus and its possible control.

Diseases Attacking The Root

Black Root Rot — This disease is caused by a number of different fungi that are common in most soils. Healthy roots are white or clear while young. With age, the roots become brownish or darker on the surface and have a yellowish living core or stele. Plants affected by root rot have reduced vigor and may die. Feeder roots are killed quickly. On the main roots, darkened patches appear followed by blackening and decay of the entire root, including the core.

Winter injury, poor drainage, acid or alkaline soils are conditions that favor the attack by the root rot fungi. Failure of new set plants to become established and the dying of established plants before or during the picking season have been attributed to root rot.

The ultimate result of root rot attack is death, though the time required to accomplish this depends on factors such as soil temperature, moisture and growing practices.

Storage Mold — On new plants a number of organisms can kill a new plant. Avoid planting mold infected plants. Dipping prior to planting in a common fungicide bath is a good preventative measure that can be used.

Viruses

Viruses are identified by the symptoms expressed on the plants in the field or on indicators (plants which give a clear expression of symptoms when grafted to diseased plants). Generally the common name given to a virus disease is descriptive of the symptom pattern produced on the plant. These diseases are spread from plant by insects (vectors), chiefly aphids and leafhoppers. Once a plant becomes infected, it does not recover and all plants attached to it by runners also become infected because of the infectious agents that are carried in the plant sap.

The use of certified plants and following a full spray program provide adequate control. As well, remove any off-type plants from the field.

Weed Control

An effective weed control program entails initial identification of the weeds followed by a combination of cultural and chemical control. Don't expect eradication of all weed species but most growers can expect a significant reduction of many of the most common weeds that occur in strawberries if a program of accurate and timely herbicide application is followed.

For rates of application of recommended herbicides, see the *Guide to Chemical Weed Control.*

Sanitation

Shelterbelts, fencelines and headlands can serve as a source of reinfestation to clean fields if not kept weed free. Refer to *Guide to Chemical Weed Control* for recommendations in shelterbelts.

Cultivation equipment should be checked for weed parts such as quackgrass rhizomes adhering to it. Unclean equipment can be a source of weed spread if not kept clean.

Mulch (straw) should be weed free. Mulch can be a good source of weeds if the straw is not taken from a clean field. If straw is extremely weedy, fumigation of the stack to kill weed parts and seeds may be necessary.

Chemical Weed Control

When Preparing Land

To ensure optimum weed control throughout the entire life of the strawberry field it is essential to establish the crop in land as weed free as possible.

Where perennial weeds such as quackgrass, thistles, etc. exist do not cultivate in the fall prior to a fallow year. In the spring, shallow till to control annual weeds. If quackgrass patches are evident, cutivate around the patch so as not to disturb it. When the thistles are at the bud to bloom stage, apply Roundup or 2,4-D. A higher level of control can be expected with Roundup. To control quackgrass, apply Roundup when the grass is at least 20 centimetres (8 inches) tall and actively growing.

After application of Banvel or 2,4-D allow at least three weeks before working the field. A minimum of five days is required when applying Roundup before cultivation occurs.

In the fall prior to planting, watch for winter annuals such as stinkweed or flixweed. Control these weeds with a fall application of 2,4-D or cultivation. Winter annuals if not controlled in the fall will mature quickly in the spring making them more difficult to control.

On Newly Transplanted Strawberries

If the recommended summerfallow is followed, only weeds arising from seed should be a problem after transplanting. It is important to realize that the herbicide treatments recommended in the summer after transplanting will not control perennial weeds that arise from underground root structures such as quackgrass and thistles. The majority of weeds arising from seed can be controlled if the proper herbicide is used.

Growers using herbicides for the first time should treat only a limited area until experience is gained. Misapplication of the herbicide can lead to crop injury and/or poor weed control.

At Planting

Cultivation will be necessary to control weeds until plants are established. Once the strawberries are established herbicides can be applied over all the field or band applied over the row plus cultivation between the rows to reduce herbicide cost.

Four to Six Weeks After Transplanting

Sinbar gives effective control of barnyard grass, green and yellow foxtail, wild oats and several broadleaved weeds. Apply after mother plants are well established but before new runner plants start to root. Use the lower recommended rates on sandy soil with low organic matter and on sensitive varieties such as Earlidawn, Midway, Bounty, Micmac and Sparkle. Temporary minor foliage injury may occur after application.

Use Sinbar only on healthy, vigorous plants. Weak, diseased or injured plants are subject to serious injury. Risk of strawberry injury is reduced if 1.5 to 3 centimetres (0.5 to 1.2 inches) of rain or irrigation follows immediately after application. Sinbar must be applied accurately within recommended application rates.

Tenoran controls several broadleaf weeds such as cocklebur, groundsel, nightshade and the ragweeds. Tenoran should be applied when weeds are less than 2.5 to 5 centimetres (1 to 2 inches) tall.

Irrigate immediately after application or apply just before or during a rain. Control should be effective for three to six weeks, after which Tenoran can be reapplied to newly emerged weeds.

Application of Sinbar or Tenoran will give effective control of the weeds in the establishment year up to dormancy.

Before Mulching in Fall

Prior to mulching in the fall Sinbar or Enide can be applied to give residual control of weeds the following spring. Enide gives effective control of volunteer grains, barnyard grass and green and yellow foxtail. Sinbar controls annual grass weeds and several broadleaf weeds.

In Established Beds

Fall application of Sinbar or Enide will give effective control of weeds germinating in the spring. Perennial weeds should be watched for and controlled with spot applications of herbicide.

Tenoran can be applied in the bearing year, but not until after harvest. Remember to irrigate after application or apply just before or during a rain to obtain effective control of seedling weeds.

Sinbar can be applied after renovation to give control of germinating weeds up to dormancy. Sinbar can then be applied before mulching in fall for residual control the following year. It is important to note that fields treated with Sinbar cannot be replanted to any crops within two years after the last application as injury to subsequent crops may occur. To reduce replanting injury to subsequent crops, cultivate or plough soil thoroughly.

Enide applied immediately before mulching in fall does not leave a residue in the soil the following year. It may be considered to reduce restrictions on subsequent crops.

Cost of Production

Initially many growers are attracted to the potential high returns strawberry production is purported to offer. However,

Table 5 Strawberry Costs of Production

Operating Costs	Your Cost/ha	Cost/ha	Cost/acre*
Fuel	_____	91.95	36.78
Maintenance & Repair	_____	210.53	84.21
Chemicals	_____	132.00	52.80
Fertilizer	_____	123.60	49.44
Plants	_____	147.23	58.89
Straw	_____	171.53	68.61
Seed	_____	3.78	1.51
Taxes	_____	21.63	8.65
Insurance	_____	56.65	22.66
Telephone	_____	78.83	31.53
Hydro	_____	24.38	9.75
Association Fees	_____	21.40	8.56
Advertising	_____	66.28	26.51
Miscellaneous	_____	44.68	17.87
Interest on Operating	_____	117.38	46.95
TOTAL OPERATING COSTS	_____	$1 311.85	$ 524.72
Fixed Costs			
Land	_____	714.00	285.60
Depreciation	_____	775.63	310.25
Investment	_____	805.15	322.06
TOTAL FIXED COSTS	_____	$2,294.78	$ 917.91
Labor Costs			
Own Labor	_____	1 030.90	412.36
Hired Labor	_____	305.75	122.30
TOTAL LABOR COSTS	_____	$1 336.65	$ 534.66
TOTAL COSTS	_____	$4,943.28	$1,977.29

* Data an average of seven Manitoba growers, 1981 data.

returns vary greatly based on intensive management practices of individual growers. Total returns for experienced growers can vary from $29,000 to $36,000/hectare ($12,000 to $15,000/acre) over 4 picking years. Factors that must be considered include, risk or winter injury (0 to 100%), no revenues in the first year of establishment, high capital cost of an irrigation system, labor, etc. A study conducted in the eastern U.S. indicated that growers must produce 8,900 to 11,200 kilograms/hectare (8,000 to 10,000 lb/acre) at $1.10/kilogram ($0.50/lb) in 1980 to have positive returns. Growers should consider their potential rate of return per dollar invested similar to other businesses (i.e. greater than short term investment certificate).

New Developments

Yields of 16 443 kilograms/hectare (15,000 lbs/acre) of strawberries have been achieved using the matted row system of growing along with top management. It is felt that this yield could be commonplace among the average Manitoba grower with new developments such as new cultivars, high density plantings, fumigation of the soil, plastic mulching for winter protection and integrated pest control and day neutral plants for one year harvesting.

Present field trials are being conducted to test these concepts out under Manitoba's conditions. The key working success of these new developments will depend first on the grower employing the existing recommended practices at the highest level of efficiency.

Yields of 22 000-33 000 kilograms/hectare (20,000-30,000 lbs/acre) are being achieved in areas employing these new developments with climatic conditions similar to Manitoba.

Further Reading

— The Morphology and Physiology of the Strawberry — G. M. Darrow, reprinted by North America Strawberry Growers' Association.

— Hunger in Strawberries — Frank Johanson — 2703-5th Street, Everett, Washington, 98201 — $3.50 U.S. Funds.

— Strawberry Deficiency Symptoms — A Visual and Plant Analysis Guide to Fertilization — Albert Ulrich, MAE Monsta fa, W. W. Allen — Publication No. 409 8 — $8.00 U.S. Funds — Agricultural Science Publication — Division of Agricultural Sciences, University of California, Berkeley, California, 94720.

— The Strawberry Cultivators to Marketing — Ed. N. F. Childers — International Money Order U.S. Funds $25.00, includes postage — Horticulture Publications 3906 N.W.-310th Place — Gainesville, Florida, 32601.

— Proceedings — Illinois Strawberry School — annual publication (back issues available — $2.00-$3.00 U.S./copy, University of Illinois, Dixon Springs, Agricultural Center, Simpson, Illinois, U.S.A. 62985.

— Strawberry Deformities — B. L. Parker and Richard P. Marini, Agricultural Experiment Station, University of Vermont — Bulletin No. 693.

— Insect Pests of Strawberries in Ohio — Extension Bulletin No. 667, Agdex 232/624, $1.50 U.S. Funds, Ohio Agricultural Research and Development Center, Wooster, Ohio.

— Manitoba Insect Control Guide — available from Ag. Rep. Office or Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba, R3C 1T5.

— 1982 Guide to Chemical Weed Control — available from Ag. Rep. Office or Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba, R3C 1T5.

— Weed Seedling Identification — Agdex 640 — available from Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba, R3C 1T5.

— Strawberry Spray Recommendations — Agdex 232 — available from Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba, R3C 1T5.

— Calibration for Band Spraying — Agdex 744 — available from Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba R3C 1T5.

— Soil Testing Services in Manitoba Agdex 533 — available from Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba R3C 1T5.

— Plant Tissue Analysis Agdex 533 — available from Agriculture Publications, 200 Vaughan Street, Winnipeg, Manitoba R3C 1T5.